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ABSTRACT

The effectiveness of science experiments often are partly dependent upon the amount of classroom time available for implementation. This factor alone has frustrated many teachers who attempt to complete laboratory assignments in the allotted time period. This document provides experiments that were designed for the middle year in a 3-year biology program for grades 7-12. Each lesson is designed for 1-hour periods. This document is divided into five parts: (1) Getting Started; (2) The Cell; (3) The Flow of Life; (4) Invertebrates; and (5) Vertebrates. Some of the experiments provided discuss the following topics: (1) chemical models; (2) organic components, (3) acids, bases, and buffers; (4) cells; (5) food and respiration; (6) DNA models; (7) mitosis and meiosis; (8) gene mutations; (9) blood typing; (10) fossil boy; (11) pedigree studies; (12) invertebrates; (13) vertebrates; (14) circulatory, digestive, and respiratory systems; and (15) touch receptors. The appendices contain a glossary of terms, a list of suppliers of equipment, materials, and teaching aids, as well as an answer key. (ZWH)

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Action Biology for the First Year

Mary Pitt Davis

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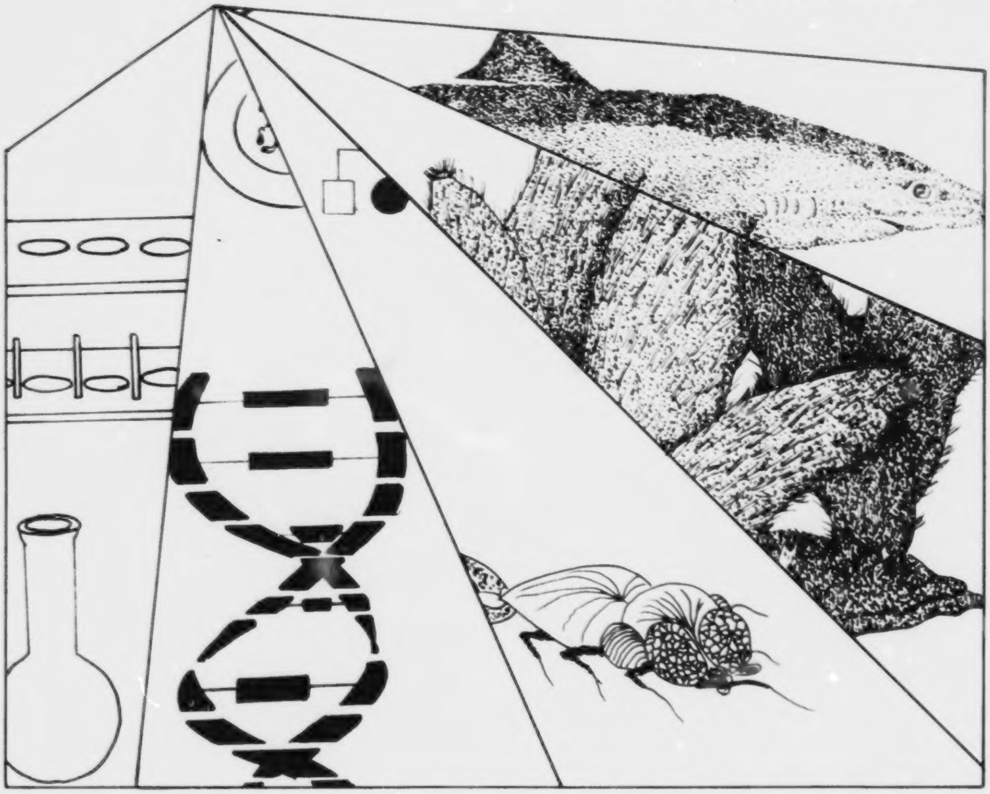
Action Biology

For the First Year

a self-contained laboratory manual — no separate teacher's manuals or student workbooks required.

by Mary Pitt Davis

assisted by Ted C. Davis



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First Edition, First Printing

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by
Mary Pitt Davis

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I dedicate this book to my mother, Mary E. Pitt,
who first showed me the wonders of life.

Preface

Over the years I have been blessed with a husband and three children, three college degrees, and sixteen years teaching experience in Washington, Japan, California, Massachusetts, Maryland, and Turkey. Following my husband around the world, first when he was a graduate student and later as a federal government employee, has led to a variety of experiences. Of these, several have had a direct impact upon my methods of teaching high school biology.

Dr. H. Weston Blaser, now deceased, my advisor and professor at the University of Washington in Seattle, greatly influenced my approach to intellectual growth and pedagogical method. Former students of his will recognize some of his methods within this laboratory manual.

The Howard County Maryland Public Schools gave me both the position and the time to test and perfect the laboratories in this manual. I have taught in many localities, but my eight years with Howard County provided the opportunity to develop, refine, and coordinate a curriculum best suited to student needs.

I would especially like to thank those teachers who routinely and cheerfully put up with my ideas and idiosyncrasies, particularly Barbara Jewett, Diane Cockrell, Bob Siskind, and Sally Cooper of Oakland Mills High School in Columbia, Maryland. For eight years we taught, shared, and tested ideas together.

I would also like to thank both Paul Keyser, science director, and the members of the Science Review Committee who studied the biological sciences program of the Howard County Public Schools in 1984. I found their comments to be thought provoking as I pursued my own ideas about a biological science curriculum for all grade levels.

Still others have assisted in ways both direct and indirect. Mrs. Judy Swanson of the George C. Marshall School in Ankara, Turkey prepared all illustrations for this manual. Mr. Clark S. Carlile, the publisher, was at all times supportive as he recommended improvements. He deserves a special thanks.

My husband, Ted C. Davis, most especially deserves credit for all that he has done. Quite simply, this book might not have been written without him. Not only did he pressure me to approach a publisher in the first place, but he spent most evenings, weekends, and holidays over the course of a year reviewing every word and critiquing every entry in this book. It gives me great pleasure to acknowledge a debt to my husband and to thank him for his forbearance with the computer and me.

Finally, I would like to thank my students over the years. After all, this book is for them.

Mary Pitt Davis

Note to Users

This self-contained laboratory manual for first year biology requires no separate teacher's manuals or student workbooks.

Biology, the study of life, is a vast and complex subject, and one in which knowledge is rapidly expanding. The needs of both instructors and students, who face a wide range of possible topics, were considered during the selection of laboratories for this manual. Those areas of biology not typically introduced in a middle school course in life science received greater focus. Upon completion of this manual, when used in conjunction with an appropriate text, the student will have satisfied all the requirements for a high school biology laboratory course. *Action Biology for the First Year*, like its companion volume, *Action Biology, Advanced Placement for the Second Year*, results from years of classroom use and testing with high school biology students.

Design Assumptions

Action Biology for the First Year is designed for the middle year in a three year biology program for grades 7-12. Middle school life science will have covered the flowering plants, birds, and other commonly seen life forms with direct meaning to the younger student. The middle school course should not be a watered-down high school biology course, but it instead should have unique content. Similarly, the second year course, and then the third year advanced placement course, should each have unique and increasingly sophisticated content. The field of biology is broad enough to provide separate examples during each of the three years. Therefore, this manual, for example, does not again cover the parts of a flowering plant, which every middle school student should have learned. Instead, the student will learn about Mendelian genetics and the invertebrates, as well as many other new topics. The advanced placement student will not repeat the Mendelian genetics of this manual, but will delve into DNA and monoclonal antibody research. Instead of repeating work on the invertebrates, the third year student will work with advanced instrumentation and study the plant kingdom, with an emphasis on the taxonomy of lower plants.

It was also assumed during preparation of *Action Biology for the First Year* that many students, including the college-bound, may not take another life science course. Therefore, many of the laboratories in this manual relate a general topic to a specific human example, e.g. genetics (your blood type and your pedigree), respiration and fermentation (the foods you eat), enzymatic reactions (your spit), etc. *Action Biology for the First Year* treats the development and function of the human body in a way meaningful to the high school student.

The number of laboratories included in this manual exceeds those required during the course of a typical five hours per week academic year. They range from the sub-cellular to the social, from the descriptive to the experimental. The five parts are: 1. "Getting Started," 2. "The Cell," 3. "The Flow of Life," 4. "Invertebrates," and, 5. "Vertebrates." The laboratories use the simplest of equipment and materials which should be available at any accredited high school. Each part includes a variety of laboratory experiences designed to aid the instructor in maintaining student interest and involvement.

Additional resources are listed at the conclusion of each discussion, exercise, or laboratory. They can be used either to introduce or reinforce the laboratory, or to assist students performing special projects. Listed audio-visuals emphasize those learning programs which require student imput, such as computer reinforcement programs, filmstrips with follow-on guides, and computer physiological testing devices.

The manual is self-contained. There are no separate teacher's manuals or student workbooks. This manual includes background information specific to the instrument or procedure, full discussion of laboratory preparations, detailed procedural steps, places for students to enter data and discuss issues, listings of additional resources, review quizzes, answer keys, etc. All in one, the teacher and student no longer will have to juggle several different manuals.

Student Objectives

Students are urged to review the objectives listed at the beginning of each laboratory or discussion and to determine, after completion of the unit, if they have accomplished those objectives. Also, students should review the terminology listed at the conclusion of each unit to verify that they know the listed words. Definitions for all words listed in the terminology sections are found in the glossary, Appendix A. Students may need to review portions of middle school life science, or gain access to a scientific dictionary, because it was assumed, when preparing the terminology lists and glossary, that general biological terms introduced during earlier years were learned at that time. Every subject has its own technical terminology, and biology is no exception. Students will have to build on previous learning and know the terms which belong to the subject.

Time Line

It was assumed that most schools operate a 50-60 minute period and that each class meets five days per week. *Action Biology for the First Year* thus is designed for one-hour periods, and the units most usefully can be used in the sequence presented in the manual. Those schools which meet in longer periods can use this manual simply by covering more than a single block during an extended laboratory session.

Action Biology for the First Year also contains exercises, as well as laboratories and discussion units. Exercises often require that the student have access to a laboratory for up to one hour of individualized effort, but such access will be possible on a flexible schedule. Exercises permit the instructor to evaluate individual efforts in large class situations. The average student will need several hours to complete most exercises in *Action Biology for the First Year*, in some cases with one hour in a laboratory and the remainder of time in class or at home.

The first part of *Action Biology for the First Year* requires at least six hours of classroom instructional time. Each of the remaining four parts of the manual require at least fifteen hours of laboratory time to complete the procedures, in addition to time for preparations, discussion, and review. The shortest laboratories are in the second part, "The Cell." As students become accustomed to working with one another and handling increasingly complex experiments, the laboratories tend to become longer and require greater student organization and team effort.

Getting Started

Part one, "Getting Started," is composed entirely of discussion sections. Only the simplest and most basic of laboratory equipment is necessary for the procedures required in *Action Biology for the First Year*, but it is essential that students know what they will be working with. Similarly, proper laboratory safety procedures and equipment usage can be slighted, unless the teacher covers safety requirements in focused detail at the very beginning of the year. For the student struggling with biological terminology, much of which is derived from classical languages, it is of great help to know the procedures whereby these technical terms are built, a subject also introduced in part one.

The Cell

The laboratories in part two, "The Cell," are primarily experimental, covering the biochemical and sub-cellular. Students will acquire a fuller understanding of life processes, as well as learn to work with their team. They also will be introduced to equipment and basic laboratory techniques. Such subjects as organic chemicals, cells, and cell division are introduced in the part two laboratories, which include a station laboratory. The discussions which introduce each laboratory cover material pertinent to the topic pursued during the procedures but not normally detailed in standard textbooks.

The Flow of Life

Part three, "The Flow of Life," contains experimental, descriptive, and reinforcement laboratories and exercises. Additionally, one laboratory has been designed as a whole class laboratory, which will require a total group effort. This part of the manual takes the student from the cellular level to community studies. Students will cover basic Mendelian genetics, as well as consider population interactions, natural selection, epidemiology, ecological issues, and classification procedures. Some of the exercises are paper and pencil exercises useful to assign around the holidays.

Invertebrates

The laboratories in part four, "Invertebrates," are primarily descriptive, and cover phyla normally not explored in a middle school course. Students will acquire a fuller understanding of the diversity of life processes and forms. Again, each descriptive laboratory begins with a discussion of a phylum and the illustrative specimen to be dissected. Classification within the animal kingdom is approached in ways which are taxonomically accurate and also indicative of the evolutionary relationships which they represent.

Vertebrates

Part five, "The Vertebrates," continues the walk through the animal kingdom begun in part four. The final twelve laboratories in *Action Biology for the First Year* emphasize both mammalian anatomy, structure, and function, as well as relate these to the student's own body. The very last laboratory requires only a few supplies, none of which are laboratory equipment or materials, so that the instructor may begin to inventory and prepare the classroom for summer recess.

Student Groups

Materials and equipment lists provided with each laboratory are for a student group composed of three to four individuals. When ordering materials or gathering equipment, the teacher will have to multiply supply requirements by the number of student groups in each class. Upon receipt of class estimates the previous spring, the teacher can estimate the number of groups and the supplies thus required.

Laboratory Preparation

All instructions for laboratory set-up are included in this manual. There is no separate teacher's guide. Your students, who may well pursue medical or scientific careers, should learn what is involved in the organization and preparation of laboratories and aid in their set-up, if at all possible. Instructors must plan in advance in order to stock all necessary supplies. This planning is best accomplished the previous spring, particularly when considering needs for chemicals, specimens, and additional equipment. Appendix B lists those suppliers with whom the author is familiar.

The Laboratory

In *Action Biology for the First Year*, procedural steps are detailed and space is interspersed for students to enter data, observations, and conclusions. Responsible students can conduct the laboratories without direct instructor supervision, once all materials and supplies are made available. In fact, some of the descriptive laboratories are self-programmed.

Student Evaluation

Student data, observations, and conclusions can be checked through periodic collection of manuals. The reviews placed on tear-out sheets at the end of each discussion or laboratory can be used either as a student self-testing and review device or as a formal quiz. If the latter option is selected, the quiz may be removed in advance. An answer key to both laboratory questions and unit reviews for the entire manual is supplied as Appendix C on tear-out sheets. Instructors may either leave these sheets in the manual for students to perform their own diagnostics, or tear them out prior to the beginning of the school year.

These laboratories and discussions are offered with the hope that they prove as useful to your biology program as they have been to mine. Over the years I have experimented, culled, and concentrated on what works best, at least cost to the school and effort to the teacher. If you have any suggestions, please let me know care of the publisher.

Mary Pitt Davis

Action Biology

for the First Year

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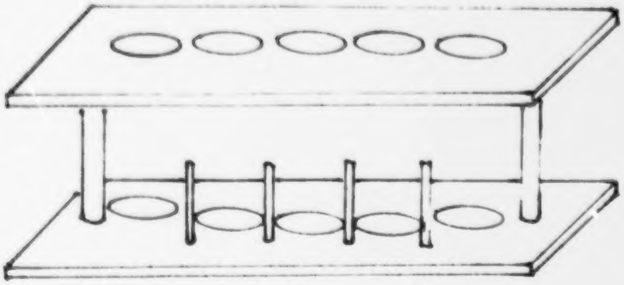
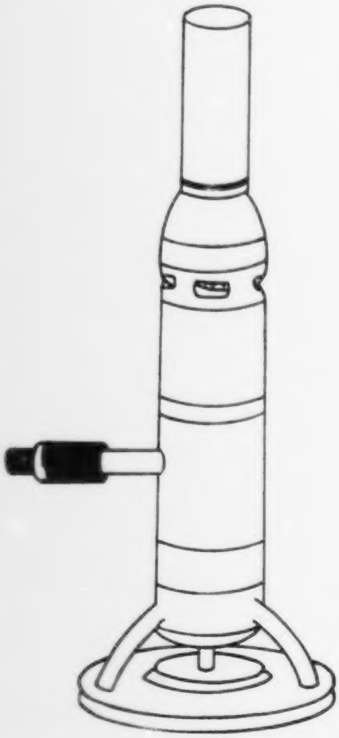
Getting Started





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1. Discussion

Laboratory Equipment

When you have completed this discussion you should be able to:

1. Identify basic laboratory equipment used in biology.
2. Show how to set up and use basic laboratory equipment.

You will spend much of your biology class time this year in the laboratory. It is here that you will study the structures and functions of living things and their relationships to one another. You will learn to use some of the methods employed by scientists: experimentation, observation, collection and interpretation of data, and drawing conclusions. Your techniques and ability to use laboratory equipment should improve with each investigation you perform. At the same time, your knowledge of living things will increase.

Listed in the figures below are some simple pieces of laboratory equipment. Study them carefully. By the conclusion of this discussion you should be able to identify and use this basic equipment.

Dissecting Equipment

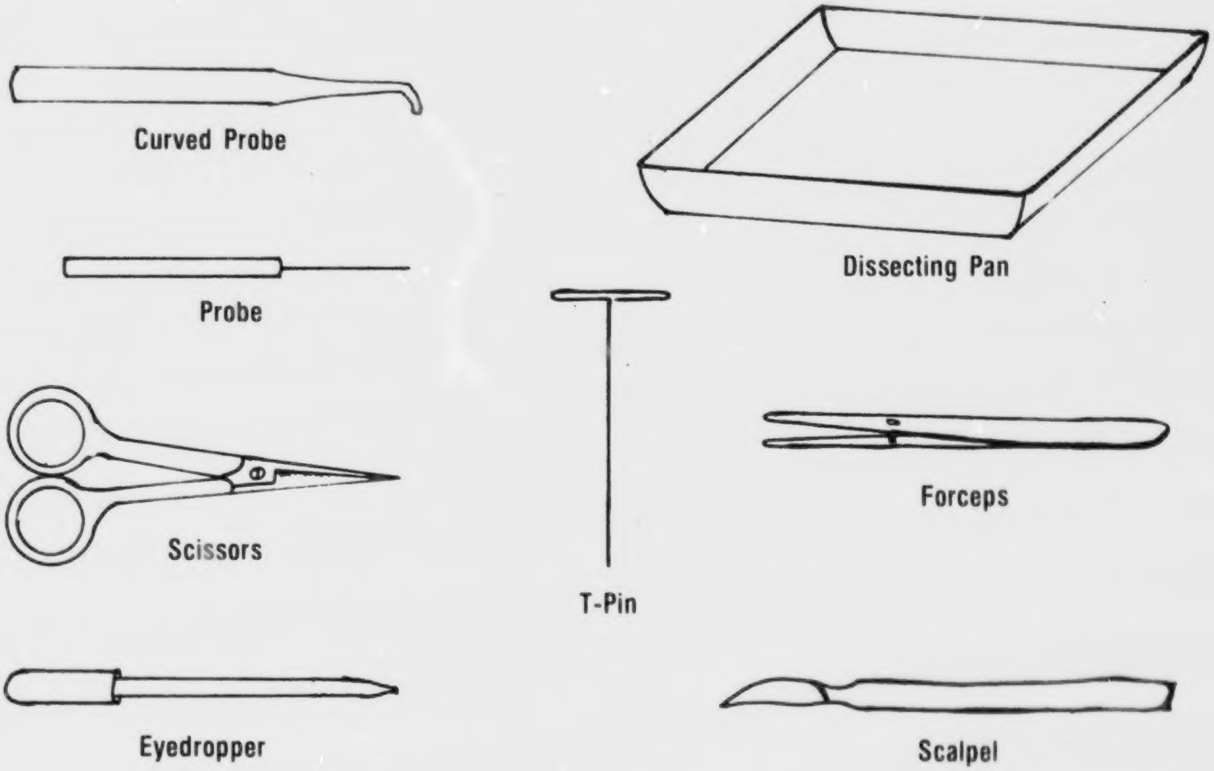


Figure 1

Glassware

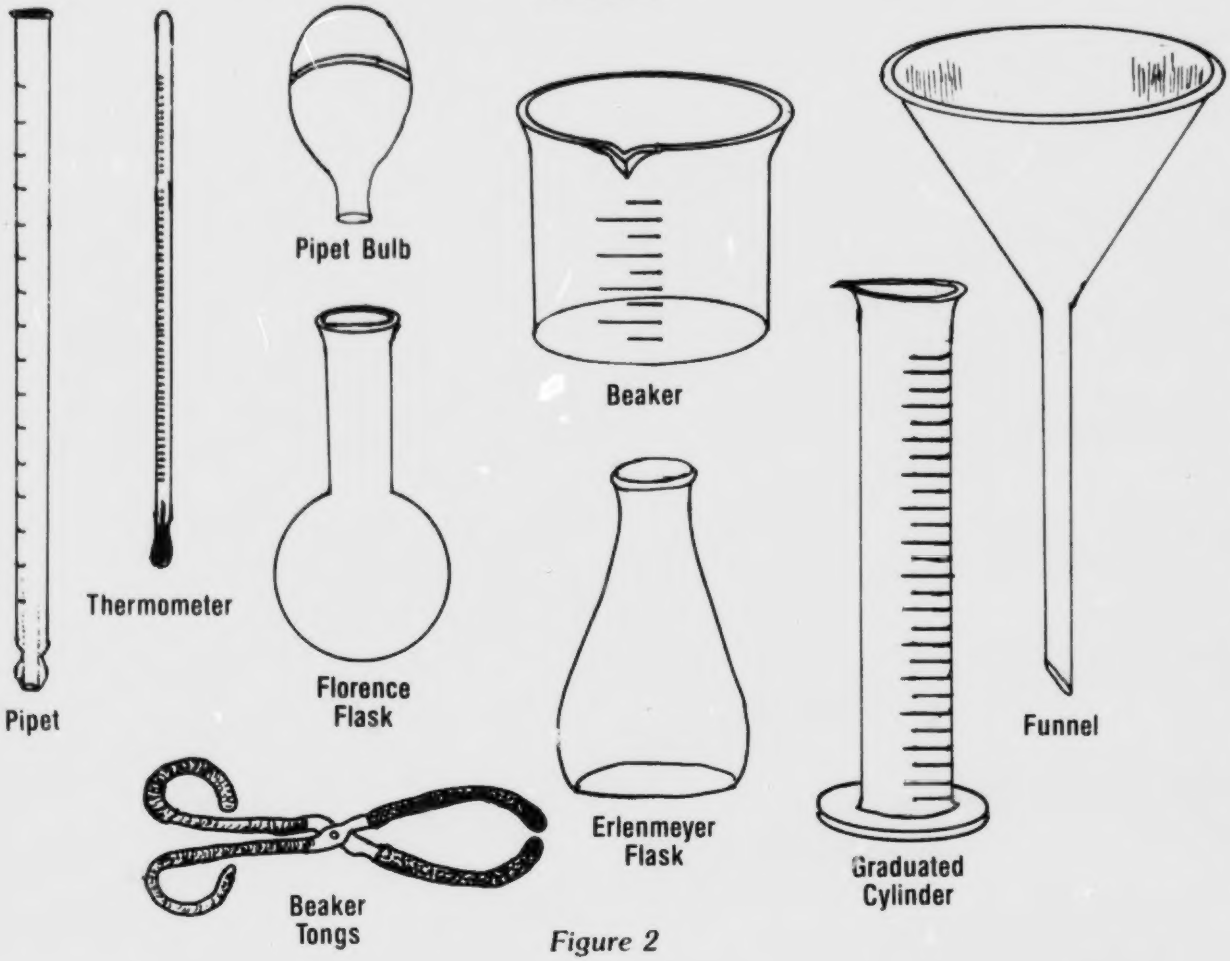

Pipet Bulb
Beaker
Thermometer
Florence Flask
Pipet
Erlenmeyer Flask
Funnel
Graduated Cylinder
Beaker Tongs

Figure 2

Tubes

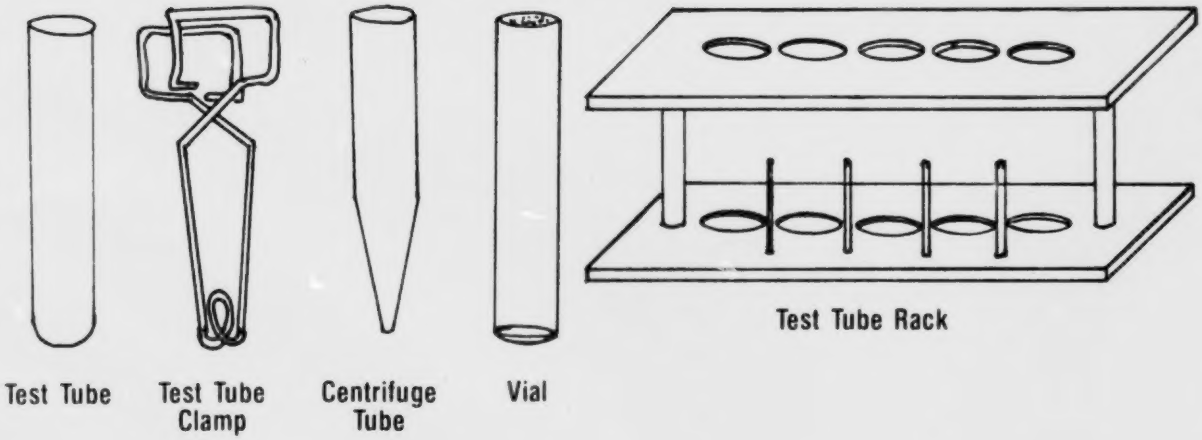

Test Tube Rack
Test Tube
Test Tube Clamp
Centrifuge Tube
Vial

Figure 3

Glassware for Observation

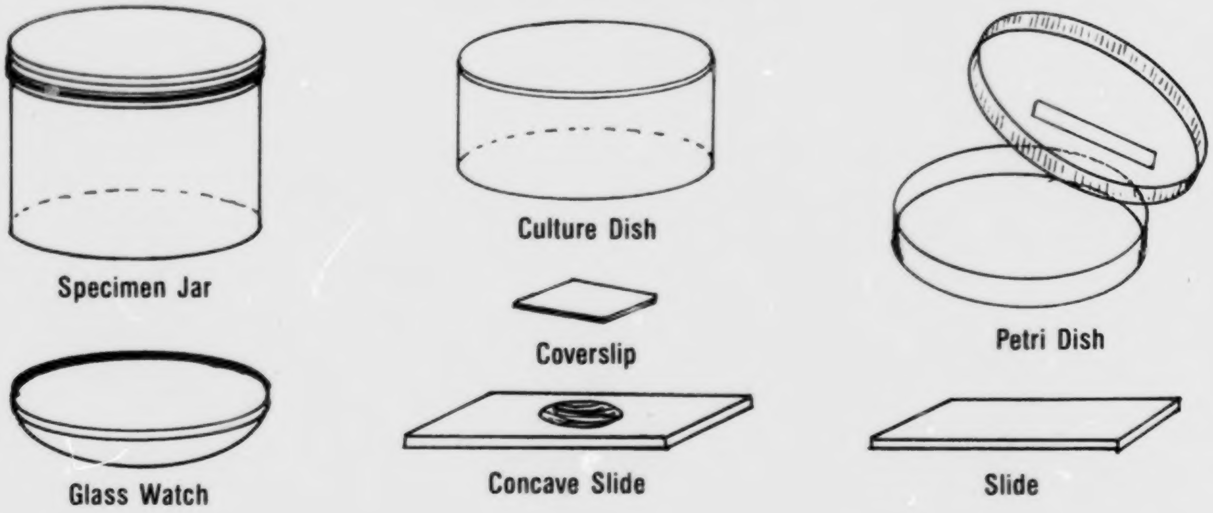

Specimen Jar
Culture Dish
Coverslip
Petri Dish
Glass Watch
Concave Slide
Slide

Figure 4

Other Helpful Equipment

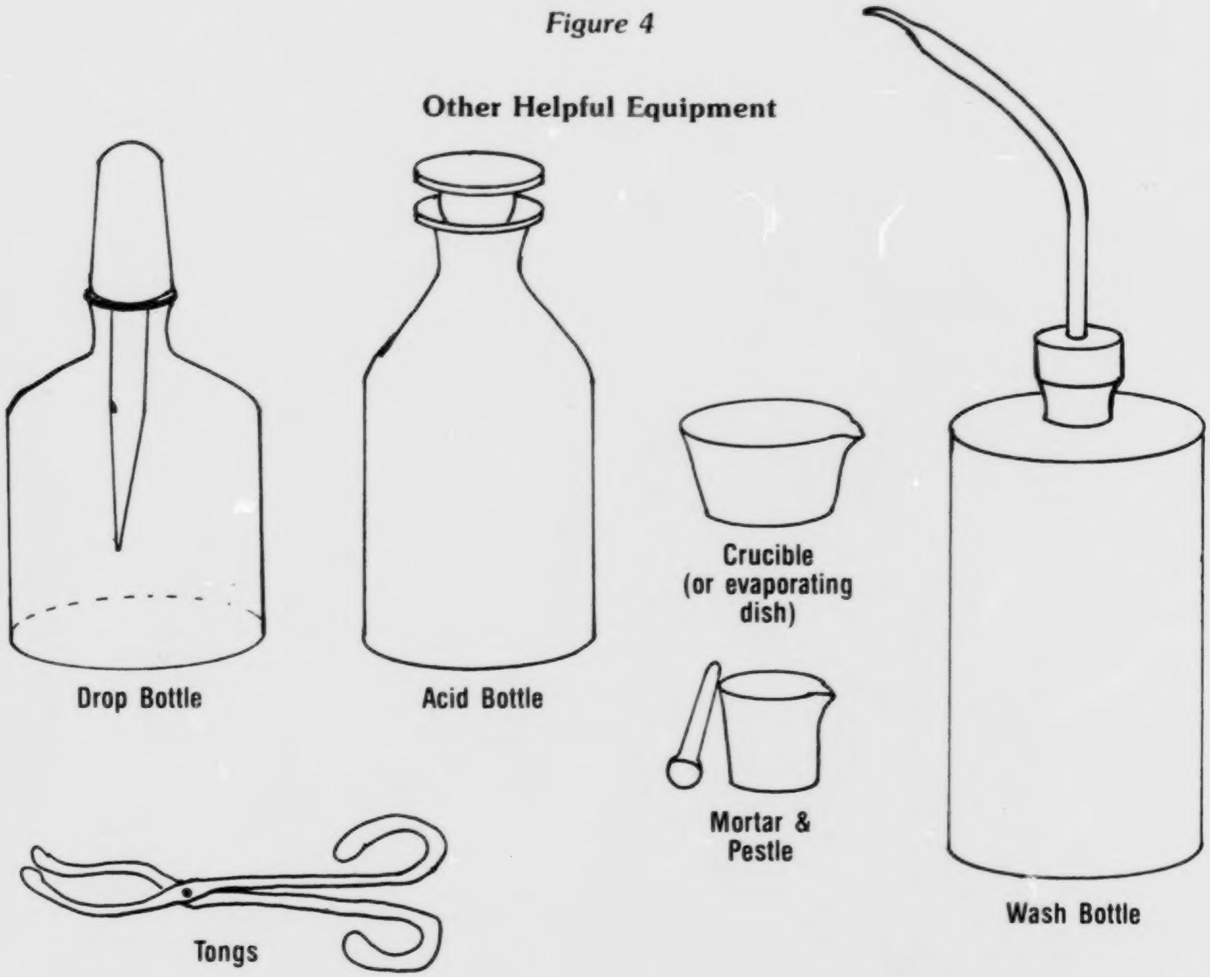

Drop Bottle
Acid Bottle
Crucible
(or evaporating
dish)
Mortar &
Pestle
Tongs
Wash Bottle

Figure 5

Heating Equipment

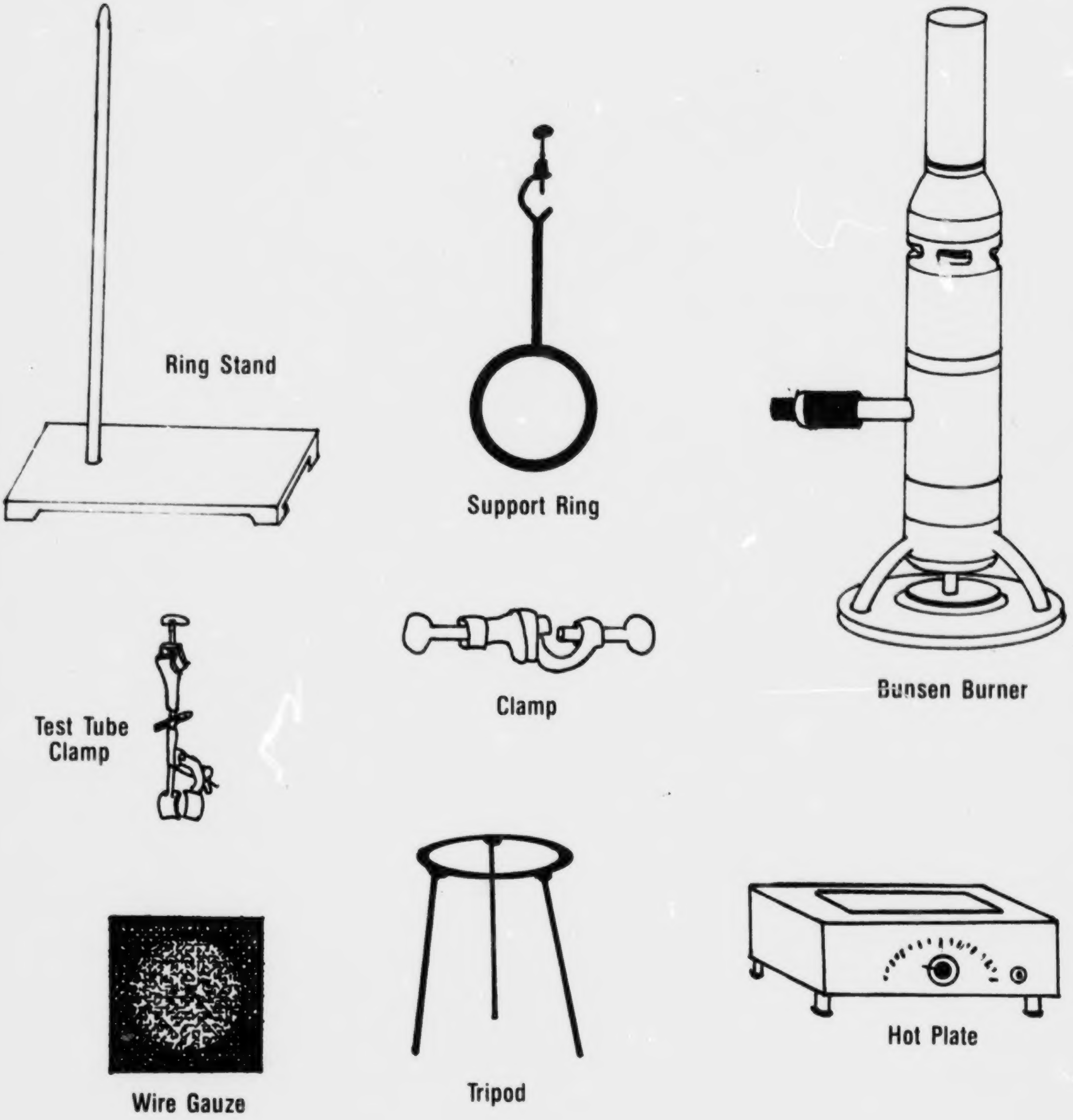

Ring Stand
Support Ring
Bunsen Burner
Test Tube Clamp
Clamp
Wire Gauze
Tripod
Hot Plate

Figure 6

You should study the equipment shown above, in figures one through six, until you recognize it on sight. Handle the equipment and discuss its uses with your teacher and classmates. During the school year, you will be asked to use still other standard equipment, such as a microscope and dissecting scope. When this equipment is first included in a laboratory, directions will be given for its use.

Review

1. Laboratory Equipment

Name ______________________________

Date ______________________________

Matching

______ 1. erlenmeyer flask

______ 2. funnel

______ 3. test tube rack

______ 4. centrifuge tube

______ 5. tripod

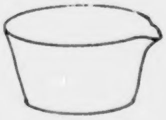
______ 6. bunsen burner

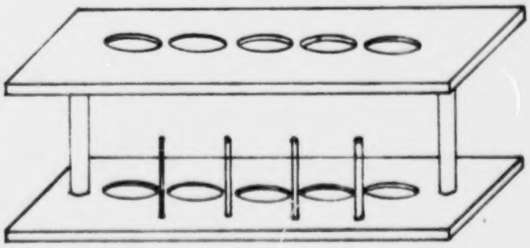
______ 7. wash bottle

______ 8. crucible

______ 9. petri dish

______ 10. forceps


a.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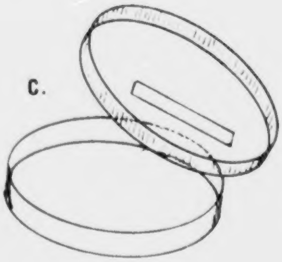
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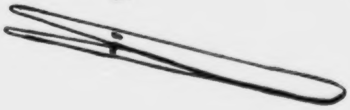
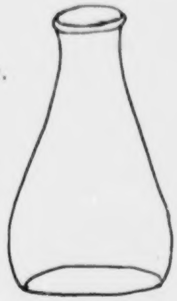
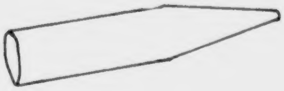
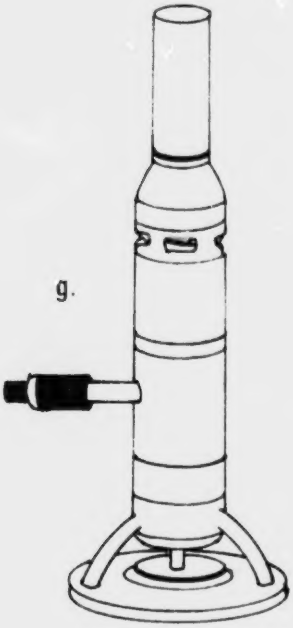
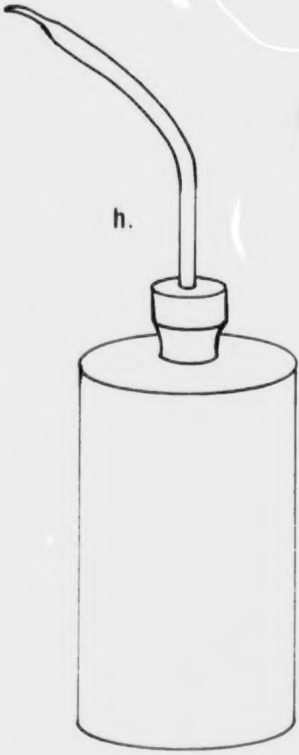
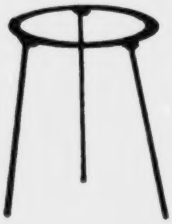

d.

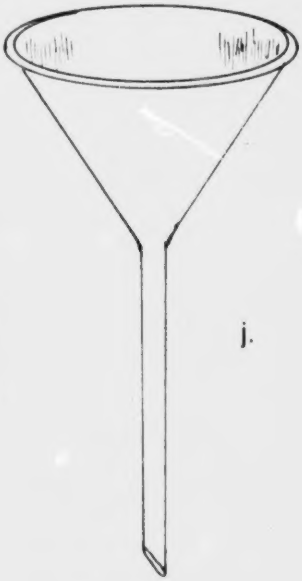

e.


f.


g.


h.


i.


j.

2. Discussion

Laboratory Safety

When you have completed this discussion you should be able to:

1. Outline safety procedures in the laboratory.
2. Perform a room inventory for safety equipment.
3. Follow safe laboratory practices during laboratory work.

Responsibility

While working in a science laboratory, you will have to be far more safety conscious than if you were in a general purpose classroom. You will work with materials and equipment which, if handled carelessly or improperly, have the potential to cause injury, or even death.

Any laboratory activity has potential hazards associated with it. If, however, you follow basic rules and use good sense, accidents can be avoided. You are responsible to yourself, and to those around you, to make sure that your work is accomplished in a responsible, careful manner.

Most laboratory accidents are caused by carelessness. It takes only a fraction of a second for an accident to occur. It is then too late to think safety. That is why we must take **precautions** — caution in advance. Preparations which eliminate dangers are the best way to achieve safety in the laboratory. If, despite your best efforts, an accident does occur, you must know what to do next.

Study the following laboratory safety procedures carefully. Understand why they are important and act accordingly.

General Laboratory Safety Precautions

1. Follow written and verbal instructions carefully.
2. Prepare for each laboratory activity by reading all instructions before coming to class, and review them again before beginning work. Make note of any modification in procedure given by the instructor. Follow all instructions precisely and with complete attention.
3. **Never** perform unauthorized laboratory activities.
4. Use only materials and equipment listed in the laboratory. If you are not familiar with how to use something, **ask** your instructor.
5. Check labels and equipment instructions carefully.
6. Know the location of all safety equipment in your classroom. This may include the closest fire alarm box, fire extinguishers, fire blankets, sand, safety showers, an eye and face wash fountain, safety goggle storage, waste disposal containers, a first aid kit, and exits.
7. Know the proper fire drill procedure, and practice it.
8. **Never** eat or drink in the laboratory. You will never know if the dust on your sandwich was yesterday's poison

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9. Approach all laboratory work with maturity. **Never** run, push, or engage in horseplay or practical jokes of any kind in the laboratory.

10. Place books, purses, and other such items in a designated storage area. Take only laboratory manuals and notebooks into the working area.

11. **Never** wear long hanging necklaces or bulky clothing in the laboratory. **Never** wear sandals or open-toed shoes in the laboratory. **Wear** goggles and laboratory aprons or coats when necessary for safety.

12. Confine long hair during a laboratory activity.

13. Keep hands away from face, eyes, and body while using solutions, specimens, equipment, or materials in the laboratory.

14. Report all accidents **immediately** to the instructor. They may be more serious than you think.

15. Wash your hands thoroughly before leaving the laboratory session.

Special Safety Precautions when Working with Heat or Fire

1. **Never** leave a hot object unattended.

2. **Never** reach over an open flame.

3. Use tongs, test-tube holders, or pot holders to handle hot laboratory objects.

4. **Never** place flammable materials, such as alcohol, near an open flame. Fumes from such materials can travel along counters and ignite.

5. **Never** point the opening of a test tube or flask at yourself or anyone else while it is being heated.

6. Use only Pyrex glass for heating.

7. Allow hot materials to cool before moving them from your laboratory station.

8. Before lighting a bunsen burner, close the valve all the way, and then open it only slightly.

9. Make sure that bunsen burner hoses fit tightly, and that they are not cracked or dry.

Special Safety Precautions when Working with Chemicals

1. **Never** taste, touch, or smell substances in the laboratory without specific directions from your laboratory instructor.

2. Use only materials from containers that are properly labeled.

3. **Never** add water to acid; acids should be slowly and carefully added to water. Generally, acid dilutions should be done by the instructor.

4. Use a fume hood or respirator when necessary.

5. **Never** carry dangerous chemicals through a cluster of students.

6. Mix heat-generating chemicals **slowly.**

7. Avoid contamination. Do not put excess chemicals back into original storage containers.

8. Do not pipet liquids by mouth. Use a rubber suction bulb to draw the liquid into the pipet.

Special Safety Precautions when Working with Electrical Equipment

1. **Never** use equipment with frayed insulation and loose or broken wires.
2. **Never** touch electrical equipment with wet hands; make sure that the area around such equipment is dry and free of flammable materials.
3. Turn off all power switches before plugging an appliance into an outlet.
4. **Never** jerk plugs from outlets, or pull them out by the cord, rather grasp the plug when disconnecting.

Special Safety Precautions when Working with Glassware

1. **Never** use broken or chipped glassware.
2. Make sure all glassware is clean before use.
3. **Never** pick up broken glassware with your hands. Use a dustpan and a brush, and then a wet paper towel to wipe-up remaining shards.
4. **Always** lubricate glass tubing, thermometers, or thistle tubes before inserting them into a stopper.
5. If a thermometer breaks, do not touch the mercury. It is poisonous and can be abosrbed through the skin. Immediately tell your instructor what has happened.

Special Safety Precautions when Working with Living or Preserved Organisms

1. If live animals are used, treat them gently. Follow instructions for their proper care.
2. **Never** cut a specimen for dissection while holding it in the air. Make sure that it is properly mounted and supported.
3. Do not open petri dishes containing live cultures unless you are directed to do so. Follow directions carefully to avoid contamination.

Your Science Laboratory

Before you begin actual laboratory work, you should know the location of all safety equipment in your science laboratory. You should also know when and how to use the equipment.

1. What is the quickest route out of the science classroom and school building in case of fire? Describe the route and procedure.

2. In the space provided below, draw a diagram of your science laboratory and identify the location of all safety equipment. This may include the closest fire alarm box, fire extinguishers, fire blankets, sand, safety showers, an eye and face wash fountain, safety goggle storage, waste disposal containers, a first aid kit, and exits.

3. In the space provided below, provide an inventory of the laboratory equipment at your laboratory station, or available to you. While making this inventory, make sure all equipment to be used by you is clean and in good condition. Notify your instructor if it is not.

4. Inventory checklist: verify the following by a check.

    ____ All glassware is properly cleaned and put away.

    ____ Bunsen burners are in safe working condition.

    ____ Electrical equipment has no frayed, broken, or loose wires.

5. Student readiness statement: parents or guardians should verify the following statement by the student.

    I, ______________________________, have read, understand, and agree to abide by the safety regulations as set forth in this discussion on safety, and also any additional printed instructions provided by the teacher and/or school district. I further agree to follow all other written and oral instructions given in class.

Date ____________________ ____
Student signature

Date ____________________ ____
Parent/guardian signature

Resources

Charles Clark Co. *Safety in the Laboratory.* KL6-21000: set of three filmloops titled "Personal Safety, Fire in the Laboratory, and Chemical Hazards."

Educational Images. *Laboratory Safety and Experimental Techniques.* EP 2128X, 20 slides with cassette.

National Fire Protection Association. *Using Fire Extinguishers the Right Way.* FL-45 film, Batterymarch Park, Quincy, MA 02269.

Review

2. Laboratory Safety

Name______________________________

Date_______________________________

Multiple choice

______ 1. Flammable materials, such as alcohol, should never be used near
a. the laboratory
b. open flames
c. people
d. the classroom

______ 2. To remove an electrical plug from its socket, you should
a. pull on the appliance
b. jerk quickly
c. pull on the cord
d. pull on the plug itself

______ 3. When heating substances in a test tube, be sure the open end of the tube points toward
a. yourself
b. your partner
c. no other person
d. any other classmate

______ 4. You should prepare for each laboratory activity by reading all instructions
a. sometime before the test
b. while you are working
c. next week
d. before coming to class

______ 5. To dilute acids you
a. pour acids slowly into water
b. pour acids into bases
c. pour water slowly into acids
d. pour water quickly into acids

______ 6. If acid gets on your skin or clothes, wash at once with
a. hydrochloric acid
b. oil
c. lots of water
d. soap

______ 7. Eyeglasses do not provide as much protection as
a. safety glasses
b. a face shield
c. safety splashproof goggles
d. any of the above

______ 8. When measuring small amounts of liquids with a volumetric pipet, draw the liquid into the pipet by using
a. your mouth
b. your thumb
c. the palm of your hand
d. a rubber suction bulb

______ 9. Whenever you are in the laboratory, you should wear
a. sandals
b. closed shoes
c. no shoes
d. open-toed shoes

______ 10. Keeping the laboratory clean is the job of
a. new students
b. the instructor
c. old students
d. everyone

Short Answer

In the space provided below, draw a diagram of your science laboratory and label the location of the following:

- exits
- fire blanket
- safety goggle storage
- emergency shower
- safety aprons
- closest fire alarm box
- fire extinguishers
- eye wash station
- waste disposal containers

3. Discussion

Science Vocabulary

When you have completed this discussion you should be able to:

1. Recognize the meanings of prefixes, suffixes, and many root words used in biology.
2. Understand how to define new words through their prefixes, suffixes, and roots.
3. Understand relationships between biology vocabulary.

Biology introduces you to many new words. In fact, understanding the vocabulary of biology is necessary to understanding the concepts of biology. Without the vocabulary of biology it is very difficult to talk about the new structures and concepts you will learn this year. The language of biology is used to name or describe living things and their parts, functions, and processes. This discussion is designed to help you meet the challenge of learning the vocabulary of biology.

It will help if you learn to examine new words part-by-part. Many of the same parts occur again and again in different words. If you learn to recognize these word parts, it will be easier to remember the meanings of the many new terms you will use this year. The same, of course, is true of new words in any subject.

New words in all languages are invented as they are needed. In biology, many words are built from Greek and Latin terms which serve as word roots. As new words are needed, scientists can add roots upon roots, like giant building blocks, and so create new words, which otherwise might take one or more complete sentence to explain.

Here are some important root words, prefixes, and suffixes used in biology. The first time through, this list may appear to be difficult, but as the year proceeds and you learn these word parts, your ability to learn new terminology, and the concepts to which they relate, will rapidly improve.

Study the list now. You may want to keep it handy as a reference tool during the rest of the year.

a, an: without. *an* emia, *an* hydrous
ab: away from: *ab* normal, *ab* scission
ad, af: near, toward. *ad* renal, *af* ferent
alb: white. *alb* umin, *alb* ino
algia: pain. neur *algia*
amphi: both. *amphi* bious
anti: against. *anti* gen, *anti* toxin
aqua: water. *aqua* tic, *aqua* rium
archae: ancient. *Archae* opteryx, *archae* ology
arthr: joint. *arthr* itis, *arthr* opod
ase: *enzyme*. lip *ase*, amyl *ase*
auto: self. *auto* biography

bi, or **di:** two or twice. *bi* ceps, *di* atomic, *di* oecious
bio: life. *bio* logy
blast: that which will germinate. *blast* ula
brachi: arm, or branch. *brachi* al

card: heart. *card* iac, myo *card* ium
carn: flesh. *carn* al
caryo, or **karyo:** nucleus of a cell. eu *caryo* te, or hetero *karyo* n
cephalo: head: *cephalo* thorax
chloro: green. *chloro* plast
chondr: cartilage. *Chondr* ichthyes
chromo: color. *chromo* some
cide: kill. insecti *cide*, pesti *cide*
coel: cavity. *coel* om
com or **con:** with. *com* munity, *con* jugate
costa: rib. inter *costa* l
cyst: capsule. *cyst*, nemato *cyst*

cyto, or **cyte:** cell. leuko cyte

decid: to cut off. *decid* uous, *decid* e
dendr: tree. *dendr* ite
dent, or **dont.** tooth. *dent* ure, ortho *dont* ist
derm: skin. epi *derm* is, *derm* is
dis, or **dys:** bad, or ill. *dis* ease, *dis* use

ec: household. *ec* ology, *ec* onomic
ecto: outer. *ecto* derm
ectomy: removal. append *ectomy*
emia: blood. an *emia*
endo: inner. *endo* derm
enter: intestine. *enter* ic
epi: on, at, or beside. *epi* dermis, *epi* boly
erythro: red. *erythro* cyte
eu: true. *eu* caryote
ex: out, or outside. *ex* terior

fer:: bearer. Roti *fer* a

gastr: stomach. *gastr* ic juice, *gastr* oenteritis
gen: producing. anti *gen*
gymn: naked. *gymn* osperm, *gymn* asium

hemo: blood. *hemo* globin
herb: non-woody plant. *herb*, *herb* arium
hepat: liver. *Hepat* icae, *hepat* ic duct
hetero: other. *hetero* sexual, *hetero* gamous
homo, or **homeo:** same. *homo* geneous
hydr: water. *hydr* ate
hyper: above, or excessive. *hyper* active, *hyper* thyroidism
hypo: below, or not enough. *hypo* thyroidism

ia, or **iasis:** disease. pneumon ia, hypochondr *iasis*, or hypochondr *ia*
ichthy: fish. *ichthy* ology
inter: between. *inter* coastal, *inter* species
intra: within. *intra* species
iso: same. *iso* ptera, *iso* gamous
itis: inflammation of. appendic *itis*

kin: motion. cyto *kin* esis

lac: milk. *lac* tose, *lac* tate
leuco, or **leuko:** white. *leuko* cyte
lysis: bursting, breaking, or dissolving. cyto *lysis*

macro: large. *macro* nucleus, *macro* scopic
mal: bad. *mal* nutrition
mega: very large. *mega* spore
meso: middle. *meso* phyll, *meso* dermis
meta: beyond, or after. *meta* morphosis
micro: small. *micro* scope, *micro* be
mito: thread. *mito* sis, *mito* spore
mono: one. carbon *mono* xide, *mono* culture
morpho: shape, form: *morpho* logy
myo: muscle. *myo* fibril, *myo* cardium

nema: thread. *nema* tode, *nema* tocyst
nephr: kidney. *nephr* itis, *nephr* idium
neuro: nerve. *neuro* logy

ology: study of. bi *ology*
oma: tumor, or swelling. sarc *oma*, lymph *oma*
omni: all. *omni* vore
ophth: eye. *ophth* almology
orni: bird. *orni* thology
ortho: straight. *ortho* dontist, *ortho* ptera
ose: sugar. sucr *ose*, lact *ose*
osis: act, or condition. acid *osis*, alkal *osis*
osteo: bone. *osteo* path
ot: ear. *ot* itis
ov, or **oo:** egg. *ovi* duct, *ov* um, *oo* cyte

para: beside. *para* thyroid, *para* llel
patho: disease. *patho* logy, *patho* gen
ped, or **pod:** foot. milli *pede*, *pod* iatrist
peri: around. *peri* cardium, *peri* cycle
phago: eating. *phago* cytosis
pheno: to show. *pheno* type
photo: light. *photo* synthesis, *photo* graph
phyll: leaf. meso *phyll*
phyt: plant. sapro *phyt* e, *phyt* ochrome
pino: drink. *pino* cytosis
plasm: form. cyto *plasm*, *plasm* a
plast: particle. chloro *plast*
poly: many, or more than three. *poly* saccharide
post: after, or behind. *post* erior
proto: first. *proto* zoa, *proto* plast
pseudo: false. *pseudo* pod
pter: wing. di *pter* a
pulmo: lung. *pulmo* nary

renal: kidney. ad *renal* glands
rhea, or **rrhea:** flow, or discharge. dia *rrhea*
rhin: nose. *rhin* itis, *rhin* oceros

sal: salt. *sal* ine
scission, or **schism:** split. ab *scission*
som: body. chromo *som* e
stom: mouth. *stom* a
sym, or **syn:** binding together. *sym* pathy, *syn* thesis

therm: heat. *therm* ometer, *therm* al
trop: turn. photo *trop* ism, geo *trop* ism
troph: nourishment. auto *troph* ic

viv: live, or living. *viv* iparous, in *viv* o
vore: to devour. carni *vore*

xero: dry. *xero* phyte

zo: animal. *zo* ology
zyg: united. *zyg* ote

Exercises

1. Can you think of other words with the same root words, prefixes, and suffixes? What is the difference between the following words? Use the meanings list above to help you.

   a. abduct ____________________

   adduct ____________________

   b. homogeneous ____________________

   heterogeneous ____________________

   c. genotype ____________________

   phenotype ____________________

   d. hyperthyroidism ____________________

   hypothroidism ____________________

   e. biology ____________________

   ecology ____________________

   zoology ____________________

   ichthyology ____________________

   ornithology ____________________

2. Analyze the following words with the aid of a good dictionary. Separate each word into its parts. Record the meaning of each part. Then write down the meaning of the combined term. Here is an example.

   ecology: (ec = household, ology = the study of). The study of the interrelationships of organisms and their environment.

   a. endocrine ____________________

   b. herbivore ____________________

   c. orthodontist ____________________

   d. endodermis ____________________

   e. ectothermic ____________________

   f. gametophyte ____________________

g. commensalism

h. metamorphosis

i. myocardium

j. protozoa

3. The technical names used to classify organisms also are made of Greek or Latin words. Analyze the following words with the aid of a good dictionary. Separate each word into its parts. Record the meaning of each part. Then write down the meaning of the combined term.

    a. *Arthropoda*

    b. *Ascomycetaceae*

    c. *Gymnospermae*

    d. *Nematoda*

    e. *Orthoptera*

Resources

Steen, Edwin B. *Dictionary of Biology*. Barnes and Noble: New York, 1971.

Review

3. Science Vocabulary

Name______________________________

Date_______________________________

Match the following root words, prefixes, or suffixes, with their meanings.

______ 1. a, or an

______ 2. cephalo

______ 3. card

______ 4. di

______ 5. ecto

______ 6. itis

______ 7. lysis

______ 8. soma

______ 9. sym, or syn

______ 10. xeros

______ 11. zyg

______ 12. osteo

______ 13. oto

______ 14. ovi, or oo

______ 15. peri

A. united

B. body

C. binding together

D. dry

E. two

F. head

G. heart

H. ear

I. egg

J. bone

K. around

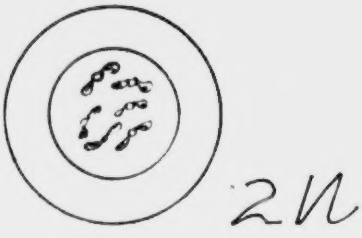
L. outer, or outside of

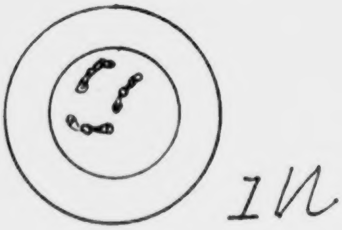
M. bursting, or dissolving

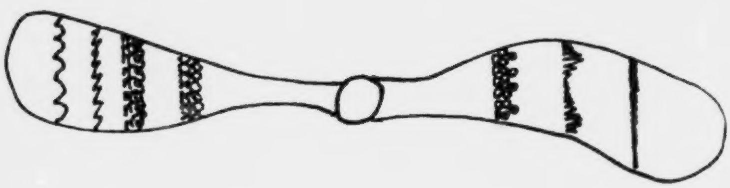
N. inflammation of

O. without

The Cell







4. Exercise

Chemical Models

When you have completed this exercise you should be able to:

1. Understand the importance of carbon, and its unique properties, in the structure of living organisms.
2. Determine the structural formulas of compounds from their molecular formulas.
3. Identify the functional groups in an organic compound.
4. Identify organic molecules such as sugars, starches, lipids, and proteins.

Carbon-based Units

Absolutely every organism on earth, both those species living now and those which are extinct, are based on the element carbon. The entire field of organic chemistry involves only compounds which contain carbon. Carbon, joined by oxygen, nitrogen, and hydrogen, are the four elements which combine to form most of the molecules in living organisms. In fact, these four elements make up more than 90% of the weight of living organisms. Other elements are present but in much smaller amounts.

The chemical substances which make up the tissues of our bodies, as well as the foods which nourish them, contain carbon. The same is true of the vitamins, hormones, and other compounds our bodies require, and of most of the medicine we use. The medical profession, as well as all branches of the biological sciences, depend upon a knowledge of organic chemistry to understand chemical processes central to life. The related field of biochemistry focuses on the study of organic chemical transformations which occur within living organisms.

The element carbon is key to the many ways in which the four elements, carbon, oxygen, nitrogen, and hydrogen, as well as other elements, combine to form living organisms. Carbon forms four covalent, or shared bonds with other elements, allowing a wide variety of molecules to be constructed. Also, extremely large molecules may be produced by hooking one carbon to another and repeating such linkages many times over. The building of such molecules, or organic chains, by living organisms is called biosynthesis. Man has learned how to do the same thing with carbon, and the process of building large molecules by hooking together repeating units of a single molecule is called polymerization. All plastics and synthetic fibers result from polymerization processes.

The Periodic Table

The periodic table also is called Mendeleyev's table of the elements. Dmitry Ivan Mendeleyev was a Russian chemist (1834-1907) who first arranged the elements in a table, using properties such as relative weights and chemical reactivities to relate each element to others with similar properties. In the periodic table, Mendeleyev arranged the elements into families, grouping those elements having similar properties and electron configurations. He even left gaps which predicted elements subsequently discovered by other chemists. Your instructor may wish to go into greater detail on the structure and character of the periodic table, since it so simply yet accurately summarizes the characteristics of all elements.

The electron configurations of elements determine their bonding patterns. For example, the halogen family (fluorine, chlorine, bromine, iodine, and astatine) all have a space in their outer electron shell for one more electron. Therefore, when they combine with other elements they usually take one electron from the other

Periodic Table of the Elements

6 — Atomic number
C — Symbol
12.0 — Atomic weight

I A	II A	III B	IV B	V B	VI B	VII B	VIII			II B	II B	III A	IV A	V A	VI A	VII A	Noble gases
								1 **H** 1.0									2 **He** 4.0
3 **Li** 6.9	4 **Be** 9.0											5 **B** 10.8	6 **C** 12.0	7 **N** 14.0	8 **O** 16.0	9 **F** 19.0	10 **Ne** 20.2
11 **Na** 23.0	12 **Mg** 24.3											13 **Al** 27.0	14 **Si** 28.1	15 **P** 31.0	16 **S** 32.1	17 **Cl** 35.5	18 **Ar** 39.9
19 **K** 39.1	20 **Ca** 40.1	21 **Sc** 45.0	22 **Ti** 47.9	23 **V** 50.9	24 **Cr** 52.0	25 **Mn** 54.9	26 **Fe** 55.8	27 **Co** 58.9	28 **Ni** 58.7	29 **Cu** 63.5	30 **Zn** 65.4	31 **Ga** 69.7	32 **Ge** 72.6	33 **As** 74.9	34 **Se** 79.0	35 **Br** 79.9	36 **Kr** 83.8
37 **Rb** 85.5	38 **Sr** 87.6	39 **Y** 88.9	40 **Zr** 91.2	41 **Nb** 92.9	42 **Mo** 95.9	43 **Tc** (98)‡	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 **La*** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac†** (227)	104 – § (260?)	105 – § (260?)	106						112?						

	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (147)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
*														
†	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (249)	99 **Es** (254)	100 **Fm** (253)	101 **Md** (256)	102 **No** (254)	103 **Lr** (256)

‡ Parentheses around atomic weight indicate that weight given is that of the most stable known isotope

§ Both Russian and American scientists have claimed the discovery of elements 104 and 105. Official names have not been adopted yet

Figure 1

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element. When halogen atoms are ionized they have electrical charges of negative one. Of the four elements most important to life, carbon bonds covalently four ways, nitrogen usually bonds three ways, oxygen bonds two ways, and hydrogen bonds one way. Study figure one on the previous page, and note the families of which these four elements are members.

1. You can find the names of more than twenty-five elements in the puzzle below, figure two. Circle the names of the elements on the scramble, and write their chemical symbols, as given in the periodic table of the elements, in the numbered spaces provided below the scramble.

Elemental Scramble

E N I D O I P A R S E N I C H G F A

N I O X S T A E B U M O C N D E N E

N T M R L K V N J R U E I I O T A L

O P Q R I L S E T O I N U Z I R I G

C A D M I U M G Y H S X W M I T O V

H M Z S A B C O P P E R O U M L N B

R U F L U S C R M S C N M I D E T A

O N D N E R S D U O Y Y U Z N A U R

M I F O G H U Y I M D M R I Y N M I

I M H B I E T H D P X A R U L M S U

U U J R T L A B O C B O E D C D I M

M L K A L I V W S D U E F L K R B J

C A L C I U M A G L E K C I N H E I

M N O P Q M B C F P O T A S S I U M

Figure 2

1) ____________________

2) ____________________

3) ____________________

4) ____________________

5) ____________________

6) ____________________

7) ____________________

8) ____________________

9) ____________________

10) ____________________

11) ____________________

12) ____________________

13) ____________________

14) ____________________

15) ____________________

16) ____________________

17) ____________________

18) ____________________

19) ____________________

20) ____________________

21) ____________________

22) ____________________

23) ____________________

24) ____________________

25) ____________________

Now let us concentrate on some important carbon compounds.

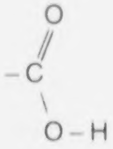
Hydrocarbons

Hydrocarbons constitute a large group of organic compounds. They contain only the elements hydrogen and carbon. Hydrocarbons are among the simplest of organic compounds. Sometimes another atom, or a group of atoms, containing elements other than hydrogen or carbon, is substituted on the hydrocarbon molecule. This substitute group is called a functional group. Biological molecules can be categorized on the basis of these functional groups.

Functional Groups

The following structural formulas for common organic functional groups are built by using chemical symbols for the elements and lines which represent bonds. One line represents one covalent bond, two lines represent a double bond, etc.

Carboxyl

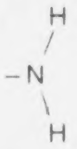


$-C(=O)-O-H$

Hydroxyl

$-OH$

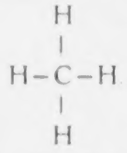
Amino



$-N(-H)-H$

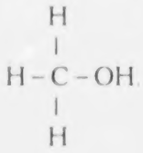
Any molecule that contains the carboxyl group is an acid. The term "fatty acid" refers to the group of organic acids that have the carboxyl group and also several H – C – H groups.

The chemical properties of an organic molecule are determined by the functional group. For example, CH_4 is a gas called methane. Its structural formula is



$$H-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-H$$

By removing one hydrogen atom and adding a hydroxyl group (–OH), the substance becomes CH_3OH, methyl alcohol. Methyl alcohol is a liquid. Its structural formula is



$$H-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-OH$$

For convenience, chemists use the letter "R" to represent the part of a molecule other than the functional group. The R can also be used to show the location of the functional group in a molecule. For example, CH_3OH could be written R – OH, where R stands for CH_3. In this way, the complete structural formula does not have to be written. The structural formula is also known as the Kekulé formula, after the Frenchman who designed it. Some biology texts refer to the structural formula as the Kekulé structure.

Even though you may now be unfamiliar with the synthesis of organic molecules, this knowledge will become more important as you continue to study biology. In figure three on page 25, the first ten alkane (single bonded) hydrogens are listed.

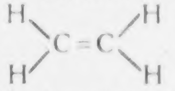
Alkanes

2. Study the name and molecular formula of the first ten alkane hydrocarbons listed in figure three and then complete the table by drawing their structural, or Kekulé, formulas. When creating your structural formulas, do not forget that carbon bonds four ways and hydrogen only one way.

Alkane Hydrocarbons		
Name	**Molecular Formula**	**Structural Formula**
1. Methane	CH_4	
2. Ethane	C_2H_6	
3. Propane	C_3H_8	
4. Butane	C_4H_{10}	
5. Pentane	C_5H_{12}	
6. Hexane	C_6H_{14}	
7. Heptane	C_7H_{16}	
8. Octane	C_8H_{18}	
9. Nonane	C_9H_{20}	
10. Decane	$C_{10}H_{22}$	

Figure 3

Alkenes

To make an alkane (single bond) hydrocarbon into an alkene (double bond) hydrocarbon, you need to insert a double bond between two carbon atoms. Thus, ethane becomes ethene, C_2H_4. The structural formula for ethene is:  $H_2C=CH_2$ In a similar manner, alkane hydrocarbons can be made into alkyne (triple bond) hydrocarbons by inserting a triple bond between two carbon atoms. Thus, ethane becomes ethyne, C_2H_2. The structural formula for ethyne is: $H-C\equiv C-H$.

3. In the table, figure four on page 26, name the first ten alkene hydrocarbons, by changing the -ane ending to -ene, and by following the conversion process discussed above. Write the alkene molecular formulas and then their structural formulas. Remember that the alkenes contain one double carbon bond.

Alkynes

4. In the table, figure five on page 26, name the first ten alkyne hydrocarbons by again using the conversion process noted above. Remember that the alkynes contain one triple carbon bond. Write their molecular formulas and then their structural formulas.

Alkene Hydrocarbons		
Name	Molecular Formula	Structural Formula
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Figure 4

Alkyne Hydrocarbons		
Name	Molecular Formula	Structural Formula
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Figure 5

Carbohydrates

Carbohydrates also are relatively simple organic compounds. They are composed of carbon, hydrogen, and oxygen. Carbohydrates are literally hydrates of carbon, or water molecules attached to carbon. For every carbon atom, there are two hydrogen atoms and one oxygen atom (CH_2O). Some examples of carbohydrates are sugars, starches, and celluiose.

Simple sugars provide the basic fuel for all cells. For example glucose, $C_6H_{12}O_6$, in the presence of oxygen and water, is used by animal cells for energy, with carbon dioxide and water given off as by-products. The over-all reaction is as follows:

$$6_6H_{12}O_6 + 6O_2 + 6H_2O \longrightarrow 6CO_2 + 12H_2O + \text{Energy}$$

It is easy to identify sugars, because the names of all sugars end with -ose, and the carbon, hydrogen, and oxygen atoms will be in a 1:2:1 ratio. Monosaccharides are a class of simple sugars consisting of only five or six carbon atoms in a chain or ring. Pentoses are sugars containing five carbon atoms, and hexoses six carbon atoms. Some common monosaccharides are glucose, fructose, and galactose.

When two monosaccharides combine, a disaccharide results. One water molecule is lost in order to join two monosaccharides. The overall reaction is as follows:

$$2C_6H_{12}O_6 \longrightarrow C_{12}H_{22}O_{11} + H_2O$$

Some common disaccharides are sucrose, or cane sugar (one glucose and one fructose molecule), maltose (two glucose molecules joined), and lactose, or milk sugar (one glucose and one galactose molecule). The reaction which results in the formation of a disaccharide, with the resultant loss of one water molecule, is called a dehydration synthesis.

Polysaccharides

Many monosaccharides joined together by dehydration synthesis results in a large molecule called a polysaccharide. Polysaccharides are commonly called complex carbohydrates. They are structured in the following manner: $(C_6H_{10}O_5)_n$, where "n" represents any large number. Most polysaccharides are thousands of carbon atoms in length.

In plants polysaccharides generally are found as chains of glucose units and are known as starches. Corn, rice, wheat, and potatoes are all examples of plants which store energy in starch molecules. Polysaccharides are stored in animals as glycogen. Glycogen is produced in the liver and stored in muscles. When quick energy is needed by the organism, glycogen can be returned to the liver, which then converts it back into glucose.

Two polysaccharides are so large that man cannot digest them. Man eats these polysaccharides in conjunction with other constituents of food. However, the indigestible polysaccharides provide only bulk in the diet, not additional calories. One such polysaccharide is cellulose, which is composed of glucose units bonded side by side. It is an extremely large, complex polysaccharide molecule. Cellulose is found in cell walls, and it is used by plants to provide rigidity. Another indigestible polysaccharide is chitin, which is a horny, complex polysaccharide produced by animals as structural support. It is found in the exoskeleton of such animals as insects, shrimp, and crabs.

5. In the space provided below, write the molecular formula for a monosaccharide, a disaccharide, and a polysaccharide.

Monosaccharide ______________________________

Disaccharide ______________________________

Polysaccharide ______________________________

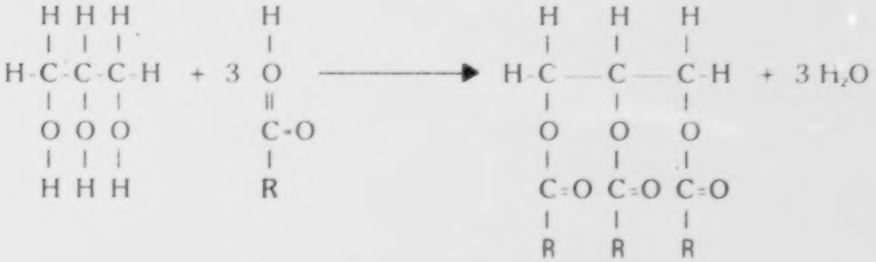
Esters and Lipids

Esters and lipids are carbohydrates which do not have a 1:2:1 ratio. The ratio of hydrogen to oxygen is in fact greater than 2:1. Both esters and lipids typically are made by the dehydration synthesis of an alcohol and an acid. Esters are mostly liquids of low molecular weight, and they give many plants and animals their distinctive odor or perfume. Esters also provide us with many solvents, such as acetone, used in both the home and industry. Lipids are of higher molecular weight and are commonly known as fats, oils, and waxes. Lipids contain more energy than carbohydrates and are the most concentrated form of food storage for an organism.

Fats are found in animal tissue and in the butterfat of milk. Oils are lower in molecular weight than fats and are liquid at room temperature. Oils typically are found in plant seeds such as cotton, soya, sunflower, and olive. Waxes are the highest in molecular weight of the lipids, and they are found both in plants (carnauba), animals (beeswax), and other organic compounds (paraffin). Carnauba wax is from the Brazilian palm, and it is commercially important as a constituent of automobile and floor waxes and also of quality candles. Paraffin is an important wax derived through petroleum refining.

The dehydration synthesis of a typical fat is shown as follows:

Glycerol + 3 Fatty Acids → Fat + 3 Water Molecules



When the reverse reaction takes place, and fat is broken down (digested) into glycerol and three fatty acids (triglycerides), water is required for the reaction. This is called hydrolysis.

Notice that the functional unit on the fatty acid is −COOH, and on glycerol, as in all alcohols, it is −OH.

6. Use the molecular formulas of the following compounds to write two dimensional structural formulas for each compound. Use the space provided in figure six below.

Name	Molecular Formula	Structural Formula
1. Methyl alcohol	CH_3OH	
2. Ethyl alcohol	C_2H_5OH	
3. Water	H_2O	
4. Glycerol	$C_3H_5(OH)_3$	
5. Acetic acid	CH_3COOH	
6. Pyruvic acid	$CH_3COCOOH$	
7. Butyric acid	$CH_3CH_2CH_2COOH$	
8. Carboxylic acid	CH_3CH_2COOH	

Figure 6

Proteins

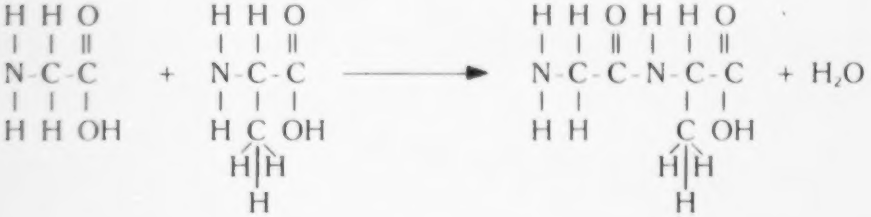
All mammals contain large quantities of proteins in such parts as muscle, skin, hair, nails, and blood. There are twenty amino acids that man must eat because his body cannot manufacture them. Three or more amino acids joined together constitute a protein. No two individuals have identical tissue proteins, except for identical twins.

The most important proteins in nature are the nucleoproteins, which are found in every cell of every living species. Nucleoproteins are involved in carrying genetic information which is necessary for cell reproduction, and they are themselves believed to be capable of self-reproduction. You will study both the structure and function of complex nucleoproteins, such as DNA and RNA, in part two of this laboratory manual.

Proteins are composed mainly of carbon, hydrogen, oxygen, and nitrogen in the form of many amino acids bonded together. The functional group of an amino acid is the amine structure: $-NH_2$. When a nitrogen is bonded to a carbon atom, it is called a peptide bond. Glycine is an example of an amino acid: NH_2CH_2COOH. Just like carbohydrates and lipids, proteins are made by the process of dehydration synthesis. Two amino acid molecules minus one water molecule form a dipeptide molecule. Polypeptides are formed when many amino acid molecules combine to form long chains. Since proteins normally are molecules with a molecular weight of 6000 or more, proteins also may be called polypeptides.

The dehydration synthesis of a typical peptide is shown as follows:

Glycine + Alanine ——→ Glycylalanine + Water
(a dipeptide)

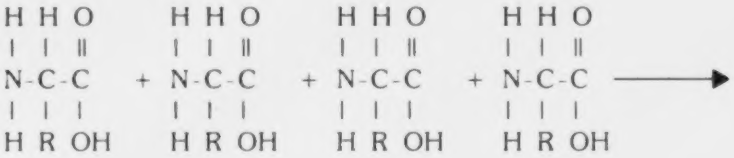


7. Use the molecular formulas of the following compounds to write two dimensional structural formulas for each compound. Use the space provided in figure seven below.

Name	Molecular Formula	Structural Formula
1. Glycine	NH_2CH_2COOH	
2. Alanine	$CH_3CH(NH_2)COOH$	
3. Valine	$(CH_3)_2CHCH(NH_2)COOH$	
4. Serine	$HOCH_2CH(NH_2)COOH$	
5. Aspartic acid	$HOOCCH_2CH(NH_2)COOH$	

Figure 7

8. Complete the reaction below and name the products.



$$\underset{\substack{| \\ H}}{\overset{\substack{H \\ |}}{N}}-\underset{\substack{| \\ R}}{\overset{\substack{H \\ |}}{C}}-\underset{\substack{| \\ OH}}{\overset{\substack{O \\ \|}}{C}} + \underset{\substack{| \\ H}}{\overset{\substack{H \\ |}}{N}}-\underset{\substack{| \\ R}}{\overset{\substack{H \\ |}}{C}}-\underset{\substack{| \\ OH}}{\overset{\substack{O \\ \|}}{C}} + \underset{\substack{| \\ H}}{\overset{\substack{H \\ |}}{N}}-\underset{\substack{| \\ R}}{\overset{\substack{H \\ |}}{C}}-\underset{\substack{| \\ OH}}{\overset{\substack{O \\ \|}}{C}} + \underset{\substack{| \\ H}}{\overset{\substack{H \\ |}}{N}}-\underset{\substack{| \\ R}}{\overset{\substack{H \\ |}}{C}}-\underset{\substack{| \\ OH}}{\overset{\substack{O \\ \|}}{C}} \longrightarrow$$

Resources

Elements of Change. #0324-0124-1-1. Films Incorporated. 1144 Wilmette Avenue. Wilmette. Illinois 60091.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

alkane
alkene
alkyne
amino acid
biosynthesis
carbohydrate
cellulose
chitin
covalent
dehydration synthesis
disaccharide
ester
functional group
glycogen
hydrocarbon
hydrolysis
lipid
monosaccharide
nucleoprotein
organic compound
peptide bond
periodic table
polymerization
polysaccharide
protein
structural formula
triglyceride

Review

4. Chemical Models

Name________________________________

Date________________________________

Matching: place the correct letter(s) to the left of the number (letters will be reused)

A. carbohydrate
B. lipid
C. protein

______ 1. made of amino acids

______ 2. sugars, starches, and cellulose

______ 3. fats, oils, and waxes.

______ 4. H:O = 2:1

______ 5. hydrolysis

______ 6. dehydration synthesis

______ 7. sucrose

______ 8. made of C, H, O, N, and sometimes other elements

______ 9. $(C_6H_{10}O_5)n$

______ 10. glycerol and three fatty acids

Fill in the blanks

11. When three or more simple sugars are combined, a ______________________________ is formed.

12. When glucose combines with fructose, ______________________________ (a disaccharide) is formed.

13. Cellulose gives plants support and strength because glucose units bond ________________________.

14. Lipids are stored in plants as ____.

15. Any chemical compound containing a COH unit is known as a(n) ________________________.

16. Any chemical compound containing a COOH unit is known as a(n) ________________________.

17. The joining of amino acids forms a(n) ______________________________________ bond.

Matching (place letter next to matching numbered term)

______ 18. glucose

______ 19. disaccharide

______ 20. starch

______ 21. methane

______ 22. ethane

______ 23. ethene

______ 24. propyne

______ 25. glycerol

______ 26. alcohol

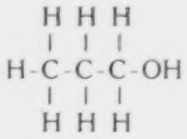
______ 27. peptide bond

______ 28. dipeptide

______ 29. fatty acid

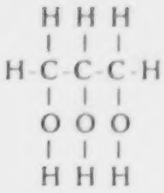
______ 30. carboxylic acid

A.



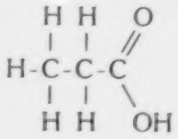
$$\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & OH \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

B.



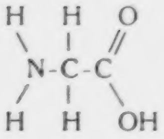
$$\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & \\ & & O & & O & & O & & \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

C.



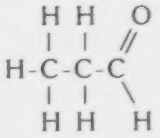
$$\begin{array}{ccccccc} & & H & & H & & O \\ & & | & & | & & // \\ H & - & C & - & C & - & C \\ & & | & & | & & \backslash \\ & & H & & H & & OH \end{array}$$

D.



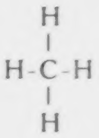
$$\begin{array}{ccccccc} H & & & & H & & O \\ & \backslash & & & | & & // \\ & & N & - & C & - & C \\ & / & & & | & & \backslash \\ H & & & & H & & OH \end{array}$$

E.



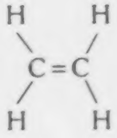
$$\begin{array}{ccccccc} & & H & & H & & O \\ & & | & & | & & // \\ H & - & C & - & C & - & C \\ & & | & & | & & \backslash \\ & & H & & H & & H \end{array}$$

F.



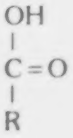
$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & H \\ & & | & & \\ & & H & & \end{array}$$

G.



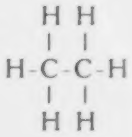
$$\begin{array}{ccccc} H & & & & H \\ & \backslash & & / & \\ & C & = & C & \\ & / & & \backslash & \\ H & & & & H \end{array}$$

H.



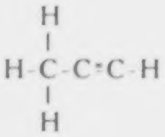
$$\begin{array}{ccc} OH & & \\ | & & \\ C & = & O \\ | & & \\ R & & \end{array}$$

I.



$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

J.



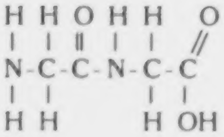
$$\begin{array}{ccccccccc} & & H & & & & & & \\ & & | & & & & & & \\ H & - & C & - & C & \equiv & C & - & H \\ & & | & & & & & & \\ & & H & & & & & & \end{array}$$

K. $(C_6H_{10}O_5)_N$

L. $C_{12}H_{22}O_{11}$

M. $C_6H_{12}O_6$

N.



$$\begin{array}{ccccccccccc} H & & H & & O & & H & & H & & O \\ | & & | & & \| & & | & & | & & // \\ N & - & C & - & C & - & N & - & C & - & C \\ | & & | & & & & & & | & & | \\ H & & H & & & & & & H & & OH \end{array}$$

5. Laboratory

Organic Compounds

When you have completed this laboratory you should be able to:

1. Test for the presence of carbon.
2. Carry out a laboratory test for a monosaccharide, a polysaccharide, a protein, and a lipid.
3. Determine whether the following substances are present in certain foods: monosaccharides, polysaccharides, proteins, and lipids.

Organic Nutrients

Life requires energy-using chemical processes. Living organisms such as plants obtain energy directly from the sun. They are called autotrophs, which means they supply their own food. Some organisms, such as man, must obtain their energy by feeding on other organisms. These feeding organisms are called heterotrophs. Be the organism an autotroph or heterotroph, its energy is stored within its cells in the high energy bonds of ATP, or adenosine tri-phosphate. This compound fuels the life processes of all cells.

The food requirements of heterotrophs are supplied by four basic food groups. These are sugars, starches, fats, and proteins. The purpose of this laboratory is to demonstrate how to test for these compounds and how to determine their presence in the foods you eat.

Pre-Lab

Supplies needed:

Equipment

bunsen burner
test tube holder
10 ml. graduated cylinder
ring stand
wire mesh screen
50 ml. graduated cylinder
goggles
protective apron
test tube rack
30 test tubes
500 ml. beaker
grease pencil
crucible
crucible tongs
matches, or striker
glass stirring rod

Materials

5 unknown solutions
5 food samples
brown kraft paper
granulated sugar
50 ml. concentrated (18 M) sulfuric acid
3 ml. ninhydrin solution
3 ml. Benedict's solution
3 ml. Gram's iodine solution
3 ml. Sudan III solution

Special Preparations

1) Prepare five unknown solutions before class. Label five one-liter flasks #1 through #5. Add various sugars, starches, proteins, and lipids to the flasks. Fill the flasks with water and stir until everything is dissolved. Keep track of what is in each flask, so that you will know if the students are testing the solutions properly.

Suggested materials include karo syrup, granulated sugar, dried potato flakes, cornstarch, egg yolk, macerated liver, salad oil, butter, etc. Supply each flask with a large pipet, so that students will be able to obtain test samples easily.

2) The five food samples may either be provided by the instructor, or each laboratory group may be given responsibility for bringing in their own samples for testing. If a food sample is in solid form, it must be mashed or otherwise softened and put into solution with the addition of water.

3) The first test, for the presence of carbon, may be done either as a demonstration by the instructor, or by each laboratory group. This first test can **only** be done by the entire class **if** the students have no difficulties following directions and exercising care in the handling of a strong acid. Sulfur dioxide fumes are generated when sugar and sulfuric acid are combined, and adequate room ventilation is essential.

4) Ninhydrin solution: add 0.1 g. ninhydrin to 99.9 ml. 95% ethyl alcohol.

5) Benedict's solution: dissolve 173 g. sodium citrate and 100 g. sodium carbonate in 700 ml. water with the aid of heat. Filter. Dissolve 17.3 g. copper sulfate in 100 ml. water. Slowly combine the two solutions. Add water to make a total volume of 1 liter.

6) Gram's iodine: dissolve 1 g. iodine crystals and 2 g. potassium iodine in 300 ml. distilled water.

7) Sudan III solution: add 1 g. Sudan III to 100 ml. 95% ethyl alcohol. If the solution is not saturated, add a little more Sudan III.

8) It is most convenient to prepare dropper bottles with the four solutions for each student laboratory group.

Time Required

The organic compounds laboratory requires one and a half classroom hours, in addition to preparations, discussion, and review.

Procedure: Partial Hour 1

Students (or the instructor) need the following: 500 ml. beaker, sugar, 50 ml. 18 M sulfuric acid, 50 ml. graduated cylinder, glass stirring rod, bunsen burner, ring stand, wire mesh screen, matches or striker, goggles, protective apron, crucible, and crucible tongs.

This first partial hour may be conducted as a demonstration by the instructor.

Carbohydrates, when placed under extreme heat, turn black. This is one of the chemical properties of carbon. Carbon turns black regardless of how the heat is applied. In this part of the laboratory, the instructor, or responsible students, will give two demonstrations to prove that sugar contains carbon and that the heat of reaction may be accomplished in more than one way.

Steps

A. Set up the ring stand, wire screen, and bunsen burner.

B. Pour a little sugar in the bottom of the crucible, and also fill the 500 ml. beaker approximately half full of sugar.

C. Put on apron and goggles, and obtain 50 ml. 18 M sulfuric acid. Place it near the 500 ml. beaker half filled with sugar.

D. Place the crucible with sugar on the ring stand, and light the bunsen burner. Heat the crucible until the reaction is complete.

1. What happens to sugar crystals when heated? ______________________________

2. If the reaction had been stopped before all water had been driven off, what would the products of this reaction have been called? ______________________________

3. In the space provided below, write the molecular formula (also called empirical equation) for the reaction which you just observed.

E. Pour 50 ml. sulfuric acid (H_2SO_4) on the sugar in the 500 ml. beaker. Stir quickly and observe what happens.

This experiment is also known as the "black pillar." It is reported that this is the first chemistry experiment which aroused the curiosity of a young boy named Linus Pauling, who went on to receive two Nobel Prizes.

4. What reaction occurs in this step? ______________________________

5. In the space provided below, write the structural equation for the reaction which you just observed.

Procedure: Hour 2

Students need the following: 500 ml. beaker, bunsen burner, test tube rack, test tube holder, 30 test tubes, 500 ml. beaker, ring stand, grease pencil, wire mesh screen, matches or striker, goggles, protective apron, 5 unknown solutions, 5 food samples, 3 ml. ninhydrin solution, 3 ml. Benedict's solution, 3 ml. Gram's iodine solution, 3 ml. Sudan III solution, and a piece of brown kraft paper (grocery or lunch bags are a fine source).

During this laboratory hour you will test five unknown solutions, as well as five food samples, for the presence of the following organic nutrients: simple sugar, starch, lipid, and protein.

Steps

A. Set up the ring stand, wire screen, and bunsen burner. Fill the 500 ml. beaker half full of water, and place it on the ring stand. Put on a protective apron and goggles, and light the bunsen burner. You will heat the beaker so that it becomes a boiling water bath.

B. While one member of the laboratory group sets up and gets the water bath up to temperature, step A, another person should label 5 test tubes #1 through #5, and place them in a test tube rack. Fill the test tubes half full of the respective unknown solutions #1 through #5.

C. Add ten drops of Benedict's solution to each of the five test tubes. Shake gently to mix. Place the numbered tubes into the boiling water bath. Observe any changes that have taken place in the test tubes after ten minutes have elapsed.

When Benedict's solution (blue in color) is added to a simple sugar (monosaccharide) in solution which is then heated, it will turn an orange or brick-red color. If the reaction is only partial, or if there is only a little simple (also called reducing) sugar in the solution, the blue Benedict's solution will only turn green. This is a standard test for the presence of simple sugars.

6. Record your results in the chart, figure one.

D. Repeat steps B and C, using five food samples in water solution which either you or the instructor have provided.

7. Record your results in the chart, figure one.

E. Obtain 10 more test tubes. Label five of them #1 through #5 and the other five with the names of the five food samples in solution. Fill the test tubes half full of the respective unknown solutions #1 through #5 and five food samples. Add two or three drops of Gram's iodine to each test tube. Observe.

Gram's iodine is red-brown in color. In the presence of starch it immediately changes to a blue-black color.

8. Record your results in the chart, figure one.

F. Wash the test tubes used in step E. Once again half fill them with unknown solutions #1 through #5 and the five food samples in solution. Add 10 drops of ninhydrin solution to each test tube, and place them in a boiling water bath. Observe any changes which have occurred after five minutes.

The presence of protein can be detected by adding ninhydrin to a food sample and heating it. Ninhydrin is colorless, but in the presence of protein and heat it will change to blue or purple.

9. Record your results in the chart, figure one

G. Obtain ten more test tubes and label them #1 through #5 and with the names of the five food sample solutions. Again half fill them with unknown solutions #1 through #5 and the five food samples in solution. Add 5 drops of Sudan III solution to each test tube and shake gently.

H. Draw ten circles on brown kraft paper (a piece approximately the size of a lunch bag) and label the ten circles #1 through #5 and with the names of the five food sample solutions. Place one drop of unknown solutions #1 through #5 and the five food samples in solution within each appropriate circle. Allow these spots to dry.

Brown kraft paper and Sudan III solution are separate tests for the presence of fats and oils (lipids). Brown paper will become translucent, and remain that way even when dried, when a fat or oil is rubbed onto it. Sudan III, on the other hand, is soluble in oils, and it will diffuse into oil droplets and turn the droplets pink. If oil is present in a solution, a pink "ring" will form in a layer in the test tube.

10. Record your results in the chart, figure one.

Organic Nutrients					
Material Tested	**Sugar Test**	**Starch Test**	**Protein Test**	**Fat Test**	
				Sudan III	**Paper**
1. Unknown #1					
2. Unknown #2					
3. Unknown #3					
4. Unknown #4					
5. Unknown #5					
6.					
7.					
8.					
9.					
10.					

Figure 1

11. Name the tested samples which have more than one of the four groups present. Which food sample is nutritionally the most complete food for you?

12. Why do all sugar-containing materials not show a positive test for sugar when Benedict's solution is used?

13. What is the practical value of food testing by a nutritionist?

14. In the test for sugar, why did some tubes show a green color while others turned brick red?

15. In the test for protein, why did some tubes show a baby blue color while others turned deep purple?

Resources

Scott, Lawrence W., John W. Hill, and Peter Muto. *Chemical Investigations for Changing Times*. 4th ed. Burgess Publishing: Minneapolis, Minnesota, 1984.

Human Relations Media. *Functional Chemistry in Living Cells*. 4 filmstrips with cassettes.

Prentice-Hall. *Basic Chemistry for the Biologist*. 2 filmstrips with cassettes.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

adenosine tri-phosphate
autotroph
heterotroph

Review

5. Organic Compounds

Name____________________

Date____________________

Short Answer

1. What is a positive test for carbon?

2. What is a positive test for simple sugars?

3. What is a positive test for starch?

4. What is a positive test for proteins?

5. What is a positive test for fats and oils?

6. Name two ways in which living organisms obtain energy for life processes. Once obtained, how is this energy stored in a cell?

6. Laboratory

Acids, Bases, and Buffers

When you have completed this laboratory you should be able to:

1. Define acids, bases, and buffers.
2. Measure the pH of different substances.
3. Observe the response of a living tissue to changes in pH.

pH and Living Organisms

Many important chemical reactions that take place in living cells are affected by the presence of an acid or a base. The biologist often has to determine how acidic or basic a solution is and how this chemistry will affect the organism under study. The human maintains an average body pH of 7.40 ±0.05. A range of pH compatible with life is about 6.8 - 7.8. However, pH readings vary according to the tissue studied. For example, an athlete may have a pH as low as 6.0 in skeletal muscle after having exercised and before the body has had time to rid itself of the acidic wastes accumulated during heavy exercise. It is important to understand how acids, bases, and buffers affect living tissues.

Acids and Bases

G. N. Lewis at the University of California in 1923 defined acids and bases in the following manner:

An acid is any molecule or ion which is capable of accepting a pair of electrons from another molecule or ion;

A base is any molecule or ion capable of donating a pair of electrons to another molecule or ion.

These simple definitions reveal that an acid-base reaction is a neutralization reaction. The result is a molecule in which there is a sharing of an electron pair between a base and an acid.

This is an extremely useful definition of acids and bases. For example, HCl (hydrochloric acid) is a very strong acid. In water the acid dissociates, or breaks up, into H^+ ions and Cl^- ions. The more hydrogen ions in the water, the more acidic the solution will become.

Since bases are the chemical opposites of acids, bases accept rather than release hydrogen ions. For example, NaOH (sodium hydroxide) is a very strong base. In water this base dissociates into Na^+ ions and OH^- ions. The more hydroxide ions in the water, the more basic the solution will become. The OH^- ions will react with H^+ ions from any acid to form H_2O, or water. Pure water is neutral, neither acidic nor basic, and that is why acid-base reactions are termed neutralization reactions.

pH

Scientists have devised a scale with which to measure acidity and basicity. This scale is called the pH scale. It is linear, running from a value of zero to fourteen. Seven on the pH scale is neutral, as is pure water. Pure water contains equal numbers of hydrogen and hydroxide ions, because there is nothing in pure water to change this balance. The lower the number, the more acidic the solution. The higher the pH, the more basic the solution. See figure one.

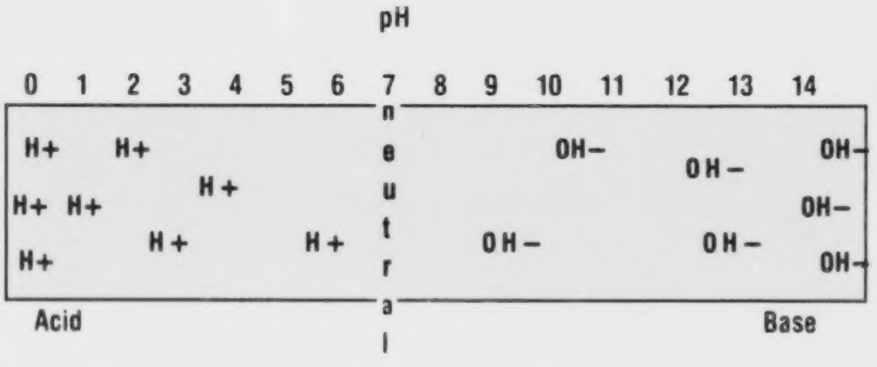


Figure 1

The pH values of different solutions can be measured precisely by means of electrical instruments called pH meters, and they also can be measured somewhat less precisely by the use of certain indicators. An indicator is any dye which is one color in an acid and another color in a base. Each indicator undergoes a color change at a different value on the pH scale. By a careful selection of indicators, one can determine most pH levels with a simple test. Paper strips impregnated with a mix of indicators are often used for such tests.

Buffers

Large changes in pH threaten living organisms. Many proteins, such as enzymes, can operate only within a narrow range of temperature and pH. Consequently, living tissue contains buffer solutions, or solutions which monitor the pH in the system so that neutrality is maintained. This ability to prevent large changes in pH is an important characteristic of many organisms.

During this laboratory you will determine the pH of certain biological materials and also observe how a buffer retards changes in pH.

Pre-Lab

Supplies needed:

Equipment

50 ml. beaker
100 ml. graduated cylinder
glass stirring rod
4 petri dishes
pH standard color chart

Materials

50 strips pH paper
4 red & 4 blue strips litmus paper
distilled water
tap water
paper and marker
5 biological materials samples
sodium phosphate solution
0.1 N hydrochloric acid solution
0.1 N sodium hydroxide solution

Special Preparations

1) Biological materials: prepare labeled stock solutions of biological materials for the entire class. The following are suggestions for four of the materials: milk, eggs, blood, urine, fruit juice, onion juice, or potato juice. Dilute so that the color of the natural material will not obscure the reading of an inserted pH strip. Each laboratory group will require only 5 ml. of each solution.

The fifth biological material should be prepared from fresh liver. Blend 10 grams of liver per 100 ml. water in a blender. Each laboratory group will require 25 ml. of the liver homogenate.

2) Prepare 25 ml. sodium phosphate solution for each laboratory group. This is a buffer solution with a pH of 7 ($NA_2HPO_4 + NaH_2H_2PO_4$).

3) 0.1 Normal HCl and 0.1 Normal NaOH is the same as 0.1 Molar HCl (3.65 g. of HCl per 1 liter of water) and 0.1 Molar NaOH (4.0 g. of NaOH per 1 liter of water).

Time Required

The acids, bases, and buffers laboratory requires one and a half classroom hours, in addition to preparations, discussion, and review.

Procedure: Partial Hour 1

Students need the following: 4 petri dishes, pH standard color chart, 8 strips pH paper, 4 biological materials samples, 4 red & 4 blue strips litmus paper, distilled water, 0.1 N hydrochloric acid solution, tap water, 0.1 N sodium hydroxide solution, paper and marker.

Steps

You will determine the pH of some solutions, as well as the pH of four biological materials during this partial hour.

A. Label four pieces of paper with the following: hydrochloric acid (HCl), sodium hydroxide (NaOH), tap water, and distilled water. Place four petri dishes on top of these labels, and pour a few milliliters of each solution into each of the appropriate dishes.

B. Dip pieces of red litmus paper into each solution and observe what happens.

1. Record your observations in the figure two chart.

C. Dip pieces of blue litmus paper into each solution and observe what happens.

2. Record your observations in the figure two chart.

D. Dip pieces of pH paper into each solution and observe what happens. Compare the color change of each pH strip with that on the pH color chart.

3. Record your numerical observations in the figure two chart.

4. When red litmus paper turns blue, what does that tell you about the solution it is testing? ______________

____

5. When blue litmus paper turns red, what does that tell you about the solution it is testing? ______________

____

6. Which is a more accurate test as to pH, litmus or pH paper? What reason can you give for your answer?

____

____

____

E. Label four pieces of paper with the names of the four biological materials you will test for acidity/basicity. Place four cleaned petri dishes on top of these labels, and pour a few milliliters of each solution into each of the appropriate dishes.

F. Dip pieces of pH paper into each solution and observe what happens.

7. Record your observations in the figure two chart.

8. Which of the materials are acidic? ______________________________

9. Which of the materials are basic? ______________________________

Material Tested	Litmus Test	pH	Acidic/Basic
1. 0.1 N HCl			
2. 0.1 N NaOH			
3. Tap Water			
4. Distilled Water			
4.			
5.			
6.			
7.			
8.			

Figure 2

Procedure: Hour 2

Students need the following: pH standard color chart, 42 strips pH paper, 0.1 N hydrochloric acid solution, tap water, 0.1 N sodium hydroxide solution, 50 ml. beaker, 100 ml. graduated cylinder, glass stirring rod, sodium phosphate solution, and liver homogenate solution.

Steps

During this laboratory hour you will test the response of a living tissue, liver, to changes in pH. You will use both tap water and the chemical buffer, sodium phosphate, as control test solutions.

A. Pour 25 ml. tap water into a 50 ml. beaker. Using a pH strip, determine its pH.

10. Record its pH in the figure three chart.

B. Add ten drops 0.1 N HCl, drop by drop, gently mixing the solution after each drop, and also testing with a pH strip after the addition of each drop.

11. Record the pH of the solution after the addition of each drop in the figure three chart.

C. Add twenty more drops of 0.1 N HCl, gently mixing the solution after every five drops, and also testing with a pH strip after the addition of every five drops. During this step the solution should be tested with a pH strip for a total of four more times.

12. Record the pH of the solution after the addition of every five drops in the figure three chart.

D. Rinse the 50 ml. beaker thoroughly, and again pour 25 ml. tap water into it. Using a pH strip, again determine its pH. It should be the same as in step A of this laboratory. If it is not, rinse the beaker, and try again.

13. Record its pH in the figure three chart.

E. Add ten drops 0.1 N NaOH, drop by drop, gently mixing the solution after each drop, and also testing with a pH strip after the addition of each drop.

14. Record the pH of the solution after the addition of each drop in the figure three chart.

F. Add twenty more drops of 0.1 N NaOH, gently mixing the solution after every five drops, and also testing with a pH strip after the addition of every five drops. During this step the solution should be tested with a pH strip for a total of four more times.

15. Record the pH of the solution after the addition of every five drops in the figure three chart.

G. You will now use the liver homogenate instead of tap water. Repeat procedure steps A through F with the liver homogenate.

16. Record your collected data in the figure three chart.

H. You will now use the sodium phosphate solution instead of tap water. Repeat procedure steps A through F with the sodium phosphate solution.

17. Record your collected data in the figure three chart.

18. Make a graph using the graph paper in figure four, plotting the changes in pH in tap water, liver homogenate, and the chemical buffer, sodium phosphate. Use a different color line for each of the three materials tested. Plot the drops of both HCl and NaOH on the vertical axis, with the number of drops of both HCl and NaOH plotted from a zero point established midway in the graph, against the pH of each material per drop acid or base, on the horizontal axis.

19. Did the liver homogenate react to acids and bases more like tap water, or more like the buffer, sodium phosphate? Why?

____

____

____

20. How can we explain the reaction of living tissues to pH changes? ____________________

____

____

____

____

Drops Added	pH Tap Water		pH Liver Homogenate		PH Sodium Phosphate	
	+HCl	+NaOH	+HCl	+NaOH	+HCl	+NaOH
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
15						
20						
25						
30						

Figure 3

21. What value are buffers to biological systems? ______________________________

Figure 4

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Resources

Carolina Biological Supply. *Water: Its Physical, Chemical, and Biological Properties.* #52-0690, 2 filmstrips with cassettes.

Focus Media. *All About Acids and Bases.* 4 filmstrips with cassettes.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

acid
base
buffer
dissociate
indicator
pH

Review

6. Acids, Bases, and Buffers

Name______________________________

Date______________________________

Multiple choice

______ 1. The pH value refers to the concentration of
a. OH^-
b. P
c. H_2O
d. H^+

______ 2. Buffers
a. act like acids
b. act like bases
c. resist changes in pH
d. are sodium hydroxides

______ 3. A solution is basic if it contains an excess of
a. indicator ions
b. neutralization ions
c. hydrogen ions
d. hydroxide ions

______ 4. The range of pH for acids is
a. 0 - 6.9
b. 7.1 - 14
c. 5 - 11
d. 6.8 - 7.2

______ 5. A material used to determine basicity/acidity of a substance is
a. litmus paper
b. iodine
c. methylene blue
d. hydrogen paper

______ 6. The liver in its reaction to changes in pH resembles more closely the reaction of
a. NaOH
b. H_2O
c. HCl
d. buffer solutions

______ 7. Substances that turn red litmus paper blue are
a. acids
b. bases
c. carbohydrates
d. indicators

______ 8. If distilled water were tested with a pH meter, its pH would be
a. 2
b. 12
c. 13
d. 7

______ 9. As the pH scale approaches the value of 12, the substance being tested has an excess of
a. OH^- ions over H^+ *ions*
b. H^+ ions over OH^-
c. Na^+ ions over Cl^- ions
d. Cl^- ions over Na^+ ions

______ 10. Solutions which resist changes in pH upon the addition of an acid or a base are called a(n)
a. acid
b. base
c. buffer
d. natural solution

Essay

Explain how the reaction of sodium phosphate to pH change serves as a model for the reaction of living tissue to changes in pH.

7. Laboratory

Spit

When you have completed this laboratory you should be able to:

1. Define the term enzyme.
2. Observe the digestion of starch by salivary amylase.
3. Determine how changing physical conditions affect the activity of an enzyme.

Ferments

People for centuries were challanged to explain common events related to food, such as the turning of fruit juices into wine, the conversion of milk into cheese, the rising of leavened bread, and the digestion of food. The origins of modern studies into enzyme reactions can be traced to attempts to explain these and similar phenomena.

The great French scientist, Louis Pasteur, demonstrated that the fermentation of grape juice, as well as the spoilage of food, is due to the presence of living organisms. He also demonstrated that these changes can be prevented by a process now called pasteurization, in which a food is heated to such a temperature that all microbes are destroyed by heat.

As Louis Pasteur conclusively proved the connection between living organisms and fermentation, another scientist proposed that fermentation is due not to the organisms themselves but rather to substances contained within the organisms. He called these substances "ferments." A compound called zymase eventually was extracted from yeast in 1897. Zymase alone can convert sugar to alcohol and carbon dioxide. It is the active digestive ingredient in yeast, the first "ferment," or as we call it today, enzyme, isolated in the laboratory.

Digestion by a stomach was at one time attributed to mechanical grinding of the food and the direct absorption of the resulting fine particles into the blood. This concept was disproved when scientists allowed animals to eat food enclosed in tiny wire cages. They were able to recover the empty cages after the food had been dissolved. Investigations into the substances responsible for dissolving, or digesting, the food in the cages, as well as other studies conducted on plant and tissue extracts, eventually led to the recognition of a group of "unorganized ferments" which we now call digestive enzymes.

Whether these "unorganized ferments" were active outside living cells, or inside, as in the case of zymase, became irrelevant when it was realized that all of these substances either originated in or were active in living cells. Scientists term all these substances "enzymes." The word enzyme is derived from the Greek and means, "in yeast."

Enzymes

What must happen to food so that your body can extract energy from it? It must be digested, or changed, into a usable energy form. The rate at which this digestion occurs is dependent upon two factors. The first is physical — the food is digested more quickly if it is reduced to tiny pieces. In humans this process begins with the teeth and is continued by churning movements of the stomach. The second factor is chemical — the food is broken down into its component molecules. A complex system of enzymes affects how this is done in your body.

Enzymes are primarily protein compounds which speed up or slow down a chemical reaction without being altered or used up by the reaction. While many enzymes are made up of protein only, some enzymes contain a non-protein component which is needed for enzymatic action. This non-protein appendage is called a coenzyme. When an enzyme must combine with a coenzyme to be effective, it is called an apoenzyme. These coenzymes may be simple metal ions, such as copper or iron, or they may be highly complex substances not easily isolated and identified. We know now that many of the vitamins and some of the minerals which are considered essential in our diet derive their importance from the role they play as coenzymes.

Almost all chemical reactions which take place in plant and animal cells require enzymes. An enzyme is specific to a chemical reaction and the compounds upon which it acts. They are named according to what they act upon. For example, the enzyme urease breaks down urea. Sucrase aids in the break down of sucrose, or cane sugar, into its component monosaccharide units. (Note the suffix " -ase.") Because enzymes are proteins, they also are affected by physical changes in the environment, such as temperature and pH. Enzymes enable reactions to occur in cells in a sequential order, quickly, and at relatively low temperatures.

Salivary Amylase

During this laboratory hour you will study the enzyme found in human spit, or saliva, called salivary amylase. Salivary amylase is an enzyme which causes starch to hydrolize, or break down. The complete digestion of starch, a polysaccharide, to glucose, a monosaccharide, takes place in stages. These steps may be followed by testing for both starch and a monosaccharide, as you learned to do in laboratory five. As the digestion of starch proceeds through the stages to completion, the iodine that yields color changes will vary from blue-black (undigested starch) to red (intermediate compounds) to no color change at all (starch digestion completed).

Pre-lab

Supplies needed:

Equipment

- 7 test tubes
- test tube rack
- 500 ml. beaker
- test tube holder
- grease pencil
- matches or striker
- 10 ml. graduated cylinder
- bunsen burner
- ring stand and wire screen
- goggles
- protective apron

Materials

- human saliva
- Gram's iodine solution
- starch solution
- Benedict's solution

Special Preparations

1) Prepare both the Gram's iodine solution and the Benedict's solution as specified in the special preparations section of laboratory five. Again, as in laboratory five, it is convenient to make these solutions available to each laboratory group in individual dropper bottles.

2) Starch solution: add 2 g. cornstarch to 10 ml. water to form a paste. Add this paste to 1 liter water and bring the solution to a boil, stirring constantly. Cool. Refrigerate for up to one week. Each laboratory group will need 25 ml. of starch solution.

3) Students will generate their own saliva during the laboratory. They **must not** eat or drink anything but water for at least two hours before this laboratory session. **Any food residue in the mouth will invalidate the results of this experiment.**

Time Required

The spit laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all the listed supplies.

Steps

A. Spit into a test tube, filling it one-fourth full of saliva. All laboratory group members may contribute to this effort. It may help to think about mouth-watering food while contributing. Sometimes something inedible, such as a rubber band, helps. **Do not put any food or drink other than water into your mouth for at least two hours preceding this laboratory. Otherwise you will contaminate your sample.**

B. Add an equal amount of water to the spit in the test tube, and gently mix it all together.

C. Number the remaining test tubes #1 through #6. Add 5 ml. starch solution to each of the test tubes #1 through #6.

D. Don both the protective apron and goggles. Set up a boiling water bath by filling the 500 ml. beaker half full of water and setting it on the ring stand under a lit bunsen burner until it comes to a boil.

E. While the water bath heats, add 3 drops of iodine solution to a cold test tube #1. Observe what happens.

1. Did a change occur? If so, what is it, and what does it signify?

F. Add 10 drops of Benedict's solution to test tube #2. Heat this solution in the boiling water bath for five minutes.

2. Did a change occur? If so, what is it, and what does it signify?

3. What do test tubes #1 and #2 represent in this experiment?

G. Add 1 ml. saliva solution to test tubes #3 and #4. Allow both test tubes to set for five minutes. While these test tubes are setting, gently bring the remaining saliva solution to a boil in the water bath. Remove from the water bath as soon as the saliva has boiled.

H. Add 3 drops of iodine solution to test tube #3. Observe any changes. Add 10 drops of Benedict's solution to test tube #4. Heat this solution in the boiling water bath for five minutes. Observe any changes.

4. Did a change occur in test tube #3? If so, what is it, and what does it signify?

5. Did a change occur in test tube #4? If so, what is it, and what does it signify?

I. Add 1 ml. boiled saliva solution to test tubes #5 and #6. Allow both test tubes to set for five minutes.

J. Add 3 drops of iodine solution to test tube #5. Observe any changes. Add 10 drops of Benedict's solution to test tube #6. Heat this solution in the boiling water bath for five minutes. Observe any changes.

6. Did a change occur in test tube #5.? If so, what is it, and what does it signify?

7. Did a change occur in test tube #6? If so, what is it, and what does it signify?

8. What conclusions can you reach about the action of salivary amylase on the digestion of starch?

9. What varied in your treatment of test tubes #1 and #3? Why is this difference important in your conclusions?

10. How did heating the saliva solution to boiling affect the action of the saliva?

11. In the space provided below, show the digestion of starch using structural formulas. Begin with starch, and note any intermediate forms, as well as naming them. Also name the final product.

Resources

James Chandler. *Enzyme Investigations.* Apple #543-00-MSAG, computer diskette for Apple II computers, with 1 backup and a teaching guide.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- apoenzyme
- coenzyme
- enzyme
- pasteurization
- salivary amylase

Review

7. Spit

Name____________________

Date____________________

Essay

1. What are some of the important properties and characteristics of enzymes?__________

2. What are the differences between enzymes, apoenzymes, and coenzymes?__________

3. Explain the action of salivary amylase upon starch. How does this affect digestion in your body?__________

8. Laboratory

The Microscope

When you have completed this laboratory you should be able to:

1. Identify the parts of a microscope and describe their functions.
2. Demonstrate microscope focusing techniques.
3. Make and study a wet mount slide.
4. Improve microscope skills while studying textile fibers and observing life in pond water.

The purpose of this laboratory is to familiarize you with the microscope. It is essential that you know how to use a microscope, since it will be used in many subsequent laboratories. Without the magnification which the microscope permits, no one could see or study the details of living systems. The microscope is an essential tool in biology and many other career fields.

Pre-Lab

Supplies needed:

Equipment

microscope coverslip slide eye dropper scissors

Materials

cheesecloth lens paper pond water newsprint textile fibers

Special Preparations

1) Collect scraps of different types of textiles. Students can cut or pull fibers from such materials as cotton, wool, linen, nylon, rayon, or polyester to obtain fibers which will show nicely under a microscope.

2) If pond water is collected more than one day in advance of this laboratory, divide the material into battery jars or fingerbowls, depending upon the size of classes. Add a few grains of rice or boiled wheat seeds and store in a cool spot. Cover loosely with several layers of cheesecloth. If possible, include some submerged or floating leaves in the pond water sample and also some bottom mud.

Time Required

The microscope laboratory requires two classroom hours, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies and materials, except for the pond water.

During this laboratory hour you will learn microscope parts and their functions. You also will learn how to use a microscope.

Remember the following:

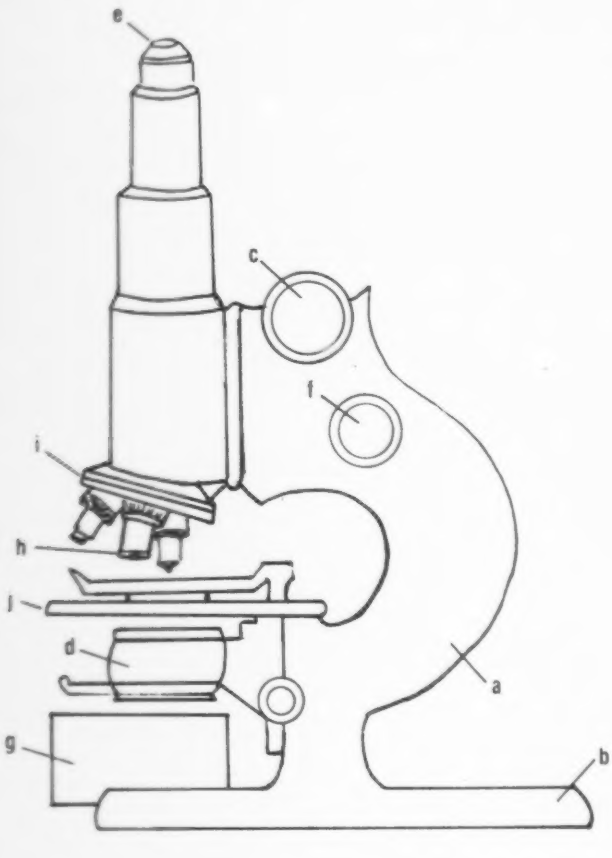
a) Always carry a microscope with one hand on the arm and the other hand under the base, and in an upright position.

b) If the microscope is electric, always have the cord completely wrapped around the microscope arm.

c) When a microscope is stored, the objectives should be on low power and at the lowest level possible.

Steps

A. Study the drawing in figure one below until you are able to identify the parts of a microscope.



a - Arm
b - Base
c - Coarse Adjustment Knob
d - Condenser
e - Eyepiece
f - Fine Adjustment Knob
g - Light Source
h - Objective Lens
i - Revolving Nosepiece
j - Stage

Microscope

Figure 1

You are now ready to use the microscope. Be sure that the arm of the microscope is facing you. The base should be at least five centimeters from the edge of the table.

B. Use a piece of cheesecloth to wipe off the stage and frame of the microscope. The stage is where the slide to be viewed is placed.

C. Lighting is extremely important to a clear field of view. Your microscope will be equipped either with a mirror or with substage lighting. Look for a microscope mirror. If your microscope is so equipped, wipe the mirror with lens paper, and turn it so that the curved surface is facing a good light source. A lamp, ceiling fixture, or indirect daylight will provide sufficient light. If your microscope has substage lighting, simply plug it into an electrical outlet and turn on the light.

D. Locate the eyepiece and the objective lenses. The objective lenses are located in a revolving nosepiece at the bottom of the microscope tube. Microscope models differ as to how these lenses are placed on the nosepiece, but all microscopes have at least a low and a high power objective. Clean both the eyepiece and objective lenses with lens paper.

1. What is the difference in function of the two objectives? ______________________________

____

E. Turn the low power objective until it is directly over the opening of the stage.

2. What magnification number is printed on the objective? ______________________________

3. What magnification number is printed on the eyepiece? ______________________________

4. Multiply the magnification of the objective with that of the eyepiece. This yields the total magnification at low power. What is the total low power magnification for your microscope?

____

A similar procedure with the high power objective and eyepiece yields the total magnification at high power.

F. Locate the diaphragm of your microscope. The diaphragm regulates the amount of light passing through the specimen. Some microscopes have a disc-type diaphragm, while others open and close an aperture much like the iris of your eye. Open the diaphragm, or turn the disc, to the largest opening so that the greatest amount of light is admitted. Now you are ready to look through the eyepiece.

5. Which type diaphragm does your microscope have? ______________________________

G. Look through the eyepiece. **Eventually it will be easiest to look through the eyepiece with both eyes open. Practice this both-eyes-open technique.**

H. Adjust the light source and/or diaphragm until you see a clear circle of bright light.

I. Obtain a microscope slide and a coverslip. Make sure both are clean. If they are not, rinse them in water and dry them with cloth or lens paper. Place a drop of water on the microscope slide. Mount some textile fibers in the drop of water on the slide. Cover the slide with a coverslip. This is called a wet mount slide. Wet mount slides are slides prepared for temporary use.

Placing the coverslip onto the slide at an angle avoids trapping air under the coverslip. Air bubbles under microscope examination look like heavy-walled, magnificent creatures. It is upsetting to look at a slide full of them and realize too late that they are only trapped air.

J. Put the slide onto the microscope stage and secure with the stage clips. Bring the fibers into low power focus with your microscope. First, lower the low power objective as far as it will go **without** hitting the slide. Be sure to watch the bottom lens as you do this. **Never** lower the objective while looking through the eyepiece. Then, as you look through the eyepiece, **slowly** raise the objective until your specimen comes into focus. Finely adjust your focus with the fine adjustment knob.

As you use a microscope you will discover that materials under study have depth as well as length and width and that you will need to change the focus in order to see details at different depths. Focus, sometimes called resolving power, is how clear and sharp a magnified image can be made. Both lighting and the ability to focus sharply are reduced as magnification is increased.

As you examine the fibers, shift the focus to different depths by turning the fine adjustment back and forth slowly.

6. Describe any changes in the appearance of the fibers. ____________________

7. Explain why these changes occur. ____________________

K. Move the fibers to the center of the low power field of view and shift to high power magnification by changing to the high power objective.

8. Compare the brightness of the low and high power fields of view. ____________________

9. Is the depth of focus as great with high power as with low power? Why or why not? ____________________

10. What is the total magnification of the high power lens? ____________________

11. How many times was the magnification increased when you changed from low power to high power? ______

12. How does this change the area of the slide included in the high power field of view? ____________________

L. Obtain a microscope slide and a coverslip. Be certain they are clean. If they are not, rinse them in water and dry them with cloth or lens paper. Cut out a lower case letter "e" from any newsprint and mount it in a drop of water on a microscope slide, placing the letter "e" on the slide so that it faces you as you would read it. Cover the slide with a coverslip.

M. Clip the wet mounted slide into place on the stage, and bring the letter "e" into low power focus.

13. Draw a picture of what you see in the space provided below.

14. How would you describe the alignment of the "e"? ______________________________

N. Move the slide to the right as you look through the eyepiece.

15. What happens if you move the slide to the right? ______________________________

16. What happens if you push the slide away from you? ______________________________

O. Describe the function of each of the following parts of the microscope.

17. Eyepiece ______________________________

18. Stage and stage clips ______________________________

19. Diaphragm ______________________________

20. Low and high power objectives ______________________________

21. Fine and coarse adjustment knobs ______________________________

22. Mirror or light source ______________________________

Procedure: Hour 2

Students need the following: microscope, eye dropper, coverslip, slide, cheesecloth, lens paper, and pond water.

During this laboratory hour you will improve your microscope skills while observing life in pond water. At this time it is not necessary to identify these life forms, unless you see something that you recognize.

Steps

A. Make a wet mount slide using a drop of water collected with an eye dropper from the surface of the pond water container that the teacher has made available to you. Observe this slide under low power of your microscope.

If you do not immediately see life, search for it by releasing the stage clips and slowly moving your slide around while looking through the eyepiece.

23. In the space provided below, sketch as many different life forms as you can see. Number your drawings, and also label them by name, if you can. Make them large enough to see and to be comparable with other drawings done by classmates.

24. Comment on the colors, mobility, and relative numbers of the different life forms you have sketched in number twenty-three above.

B. Make a wet mount slide using water collected with an eye dropper from the middle layer of the pond water container. Observe this slide under both low and high power of your microscope.

If you do not immediately see life, search for it by releasing the stage clips and slowly moving your slide around while looking through the eyepiece.

25. In the space provided below, sketch as many different life forms as you can see. Number your drawings, and label them if you can. Make them large enough to see and to be comparable with other drawings done by classmates.

26. Comment on the colors, mobility, and relative numbers of the different life forms you have sketched in number twenty-five above.

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C. Make a wet mount slide using water collected with an eye dropper from the bottom of the pond water container. Observe this slide under both low and high power of your microscope.

If you do not immediately see life, search for it by releasing the stage clips and slowly moving your slide around while looking through the eyepiece.

27. In the space provided below, sketch as many different life forms as you can see. Number your drawings, and label them if you can. Make them large enough to see and to be comparable with other drawings done by classmates.

28. Comment on the colors, mobility, and relative numbers of the different life forms you have sketched in number twenty-seven above.

29. How do the samples of life differ at each of the three separate pond water layers? What can you conclude about the organisms you have seen at those levels?

Resources

Charles Clark Company. *Microscope Techniques.* LF5-122, filmstrip, 1968.

Adams, Tom. *The Microscopic Pond.* EP 2009F, 3 filmstrips plus cassettes, or EP 2009S, 3 carousel slide trays plus cassettes, 1983.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

The microscope:

adjustment
arm
base
diaphragm
eyepiece
field of view
focus
objectives
stage
resolving power
wet mount slide

Review
8. The Microscope

Name ______________________________

Date ______________________________

Identification

Identify the parts of the microscope in the figure two drawing below.

1. ________________________
2. ________________________
3. ________________________
4. ________________________
5. ________________________
6. ________________________
7. ________________________
8. ________________________
9. ________________________
10. ________________________

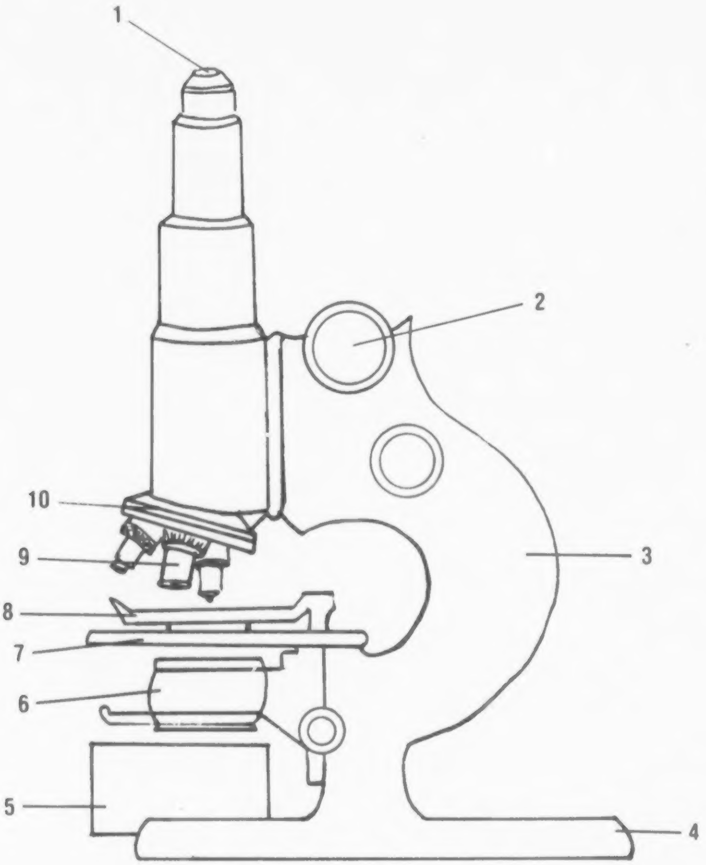

Figure 2

Short answer

11. Where should your hands be when carrying a microscope?

12. What is used to clean the eyepiece and objectives?

13. What holds a microscope slide in place on the microscope?

14. When moving the slide away from you, which way does the image move?

15. When switching the objectives from low to high power, what happens to your field of view?

16. If the number on the eyepiece is 5X and on the low power objective 12X, what is the total magnification?

17. What is meant by the resolving power of a microscope?

18. What regulates the amount of light which strikes the specimen on your slide?

19. What position should the objective be in when storing the microscope?

20. If you were to purchase a microscope, what would be some features that you would ask for?

9. Laboratory

Cells

When you have completed this laboratory you should be able to:

1. Recognize plant and animal cells.
2. Locate and distinguish between plant and animal cell structures.

Cells

The cell is the basic unit of life. Be the organism a one-celled amoeba or a many-celled whale, it is constructed of cells. Some cells are visible to the naked eye, but most are microscopic. They range from 0.1 μ (micron) to several ml. (millimeters) in diameter. A micron is equal to one millionth of a meter in length, so you can see that some cells are very tiny. A typical cell has a nucleus embedded in a jelly-like cytoplasm. The cytoplasm contains many organelles and is surrounded by a cell membrane. In plant cells, the membrane also is surrounded by a cell wall.

Eukaryotic and Prokaryotic Cells

Not all cells have a nucleus. Bacteria and blue-green algae have no defined nucleus. Cells with organelles such as the nucleus are called eukaryotic cells, or "true" cells. Cells which are more primitive and do not have distinct organelles are called prokaryotic cells, or the "cells that came before." In this laboratory you will observe only types of eukaryotic, or "true" cells.

Some eukaryotic cells are very specialized and have lost some of the organelles which typically distinguish eukaryotes. An example of this is the red blood cells of mammals, which have no nuclei during certain stages of their development.

Organelles

Embedded in the cytoplasm of eukaryotes are various structures called organelles. Many of these organelles until recently were not visible, because of the limits of the light microscope, and, in this laboratory, you will observe only organelles which are visible with the light microscope. However, in the 1930's, with the development of the electron microscope, many more organelles, as well as other cell structures, became visible.

Electron Microscope

The electron microscope is similar in concept to the light microscope, except that an electron microscope uses a beam of electrons focused through a magnetic field rather than a beam of light. Also, the image is projected on a screen. The magnification of an electron microscope is many times greater than a light microscope. One problem with an electron microscope, however, is that materials must be placed in a vacuum in order to be scanned. No cell can remain in a vacuum and live. Therefore, only dead material can be viewed with an electron microscope.

In this laboratory, you will observe several types of cells, both plant and animal, and locate internal structures visible with a light microscope. Cells are three dimensional, so adjustments to the fine focus will be necessary to study a cell and its internal structures.

Pre-lab

Supplies needed:

Equipment

- microscope
- slide
- coverslip
- colored pencils or markers
- razor blade
- scalpel
- forceps
- eye dropper

Materials

- bottle cork
- *Elodea* leaves
- human cheek cells
- human blood
- potato
- alcohol swabs
- lens paper
- flat toothpicks
- methylene blue solution
- iodine solution
- onion
- sterile lancets

Special Preparations

1) One potato, one onion, one *Elodea* stalk, and one bottle cork will suffice for at least two classes. Fresh, vigorously growing *Elodea* is required in order for students to see good examples of cytoplasmic streaming.

2) Students will supply their own cheek cells. These are obtained by using **flat** toothpicks. Students may also supply their own blood. Blood is obtained using alcohol swabs and sterile lancets. Alternatively, artificial or animal blood is available through biological supply houses.

3) Methylene blue: add 0.1 g. methylene blue powder to 1 liter distilled water.

4) Iodine solution: dissolve 3 g. potassium iodide and 0.6 g. iodine in 2 liters water. Store in a brown bottle or a dark room. Note: iodine vapor or dust is toxic. Do not inhale or touch. Flush any spills with water.

5) It is convenient to have both the methylene blue and the iodine solution available in dropper bottles, one set per laboratory group.

Time Required

The cells laboratory requires two classroom hours, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need the following: microscope, slide, coverslip, razor blade, scalpel, forceps, colored pencils or markers, bottle cork, lens paper, iodine solution, potato, and onion.

During the first part of this laboratory hour, you will repeat Robert Hooke's original experiment with cork cells. Robert Hooke was the first scientist to recognize these building blocks of life, and he gave them the name "cells." More than three hundred years have passed since Hooke first described cork cells in his book *Micrographia*.

Steps

A. Shave a **very** thin section from a bottle cork with a razor bade. Prepare a wet mount of the cork slice. Examine the specimen under low power, studying it under different focus levels and fields of view.

1. Select a view in which you are able to see individual cells. In the space provided below, draw what you see. Label any structures you can identify.

2. Are all these cells of similar shape and size? Why or why not? Explain. ____________________

2. Do the cells appear to be filled with any material? Why or why not? ____________________

3. Do you think these cells are alive? Why or why not? ____________________

During the second part of this laboratory hour, you will observe the epidermal cells of an onion. Onion epidermal cells are composed of a single cell layer, and so they are very easy to observe through a light microscope without undue disruption to their functional organization. Until you apply the iodine solution, you will be looking at functioning units of living cells.

B. Cut an onion lengthwise. Remove a thick scale (a piece of one of the rings) and peel the delicate, transparent tissue from the inner surface of the scale. Make a wet mount slide of this tissue, being careful **not** to wrinkle the tissue. Examine the cells under low power.

C. Carefully raise one side of the coverslip and add a drop of iodine solution. Iodine will stain cells so that their structure is easier to see, but it also quickly kills the cells. Again examine the cells under low power, studying it under different focus levels and fields of view.

5. Select a view in which you are able to see individual cells. In the space provided below, draw what you see. Label any structures you can identify.

D. Now examine the onion cells under high power.

6. Select a view in which you are able to have a clear field of view. In the space provided below, draw what you see. Label any structures you can identify.

7. Are all these cells of similar shape and size? Why or why not? Explain. ______________________________

____

____

____

8. What effect does the iodine solution have on the cells? ______________________________

____

9. What are the advantages and disadvantages of using an iodine staining solution? ______________________________

____

____

____

10. In different onion cells, are the nuclei always in the same position in the cell?

11. Does the onion epidermal cell have depth? Explain your answer.

12. Can you detect any movement in the cytoplasm of the cells?

13. Do you find any chloroplasts in the onion cells (chloroplasts are the organelles which contain chlorophyll, the photosynthetic pigment of most plants)? Why or why not?

14. How did the cork cells differ from onion epidermal cells?

During the third part of this laboratory hour, you will observe the storage cells of a potato. You will be able to see a plastid, or plant organelle, which has the specific function in a potato's cytoplasm of storing starch. This particular plastid is known as a leucoplast, or "clear plastid." The potato tuber functions as a food storage container for the potato plant.

E. Mash a small sample of potato tuber with the blunt end of your scalpel. Make a wet mount slide of this material, and observe under the low power of your microscope.

F. Carefully raise one side of the coverslip and add a drop of iodine solution. Iodine will stain cells so that their structure is easier to see, but it also quickly kills the cells. Also remember that iodine turns blue-black in color in the presence of starch. Again examine the cells under low power, studying them under different focus levels and fields of view.

15. Select a view in which you are able to see individual cells. In the space provided below, draw what you see. Label any structures you can identify.

G. Now examine the potato cells under high power.

16. Select a view in which you are able to have a clear field of view. In the space provided below, draw what you see. Label any structures you can identify.

17. Are all these cells of similar shape and size? Why or why not? Explain. ____________________

18. What effect does the iodine solution have on the leucoplasts? ____________________

19. What effect does the iodine solution have on the cells as a whole? ____________________

20. Do you find any chloroplasts in these cells? Why or why not? ____________________

21. Is there starch in potato cells? How do you know? ____________________

Procedure: Hour 2

Students need the following: microscope, slide, coverslip, eye dropper, forceps, razor, lancet, alcohol swab, lens paper, toothpick, *Elodea*, and colored pencils or markers.

During this laboratory hour you will observe another plant cell plastid, the chloroplast, as well as two types of animal cells. You will observe the differences between plant and animal cells. You also will observe a specialized animal cell, a blood cell.

Steps

During the first part of this laboratory hour you will observe a typical, relatively unspecialized plant cell.

A. Prepare a wet mount of an *Elodea* leaf. A whole leaf obtained from near the growing tip of the plant should be used. Examine the leaf under low power of your microscope. Find a field of view in which the cells are particularly distinct. Center this area in your microscope field, and bring it into focus under high power. Use the fine adjustment knob to observe the cells at different depths.

22. In which cell layer are the cells the widest? ______________________

B. Observe and identify the following: the cell wall, the nucleus, the central vacuole, and chloroplasts. The nucleus probably is best seen as a clear circular lump near the cell wall. The vacuole is a large clear area dominating the center of the cell. Chloroplasts are another type of plastid which appear as small, round, green bodies in the cytoplasm.

If you do not see movement among the chloroplasts, wait a few minutes, and again observe the cells. If you still do not see movement, mount a new leaf and try again.

23. Are all the chloroplasts moving in the same direction? ______________________

24. What direction? ______________________

25. Are they all moving at the same speed? ______________________

26. Can you observe anything which makes them move? ______________________

27. Explain how the chloroplasts move. Include an explanation of why waiting a few minutes with the slide mounted in your microscope increases the probability of chloroplast movement.

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28. Draw some cells of an *Elodea* leaf in the space provided below. Use arrows to indicate chloroplast movement. Label your drawing, indicating the cell wall, nucleus, vacuole, chloroplasts, and cytoplasm.

During the second part of this laboratory hour you will observe a typical, relatively unspecialized animal cell, a human cheek cell.

C. Gently scrape the inside surface of your cheek with a clean, flat, toothpick. **Do not hurt yourself. The slimy surface of the inside of your mouth has many cells which come off easily without digging into the cheek itself.** Prepare a wet mount of the material that you have scraped from your cheek. Add a drop of methylene blue to the slide and a coverslip. Examine the cells under low power. Switch to high power and observe again.

Some stains, such as iodine solution, kill cells rapidly once they come into contact with the cell. Other stains, called vital stains, kill cells slowly. Vital stains, such as methylene blue, may be used as aids in studying living cells. Methylene blue is differentially absorbed by the nucleus and also by tiny granules in the cytoplasm. Animal cells stained with methylene blue should show an obvious blue nucleus and a pale blue cytoplasm.

29. Draw your cheek cell in the space provided below. Label the cell membrane, cytoplasm, and nucleus.

30. How does the outer edge of a cheek cell compare with that of an *Elodea* leaf?

31. Describe the shape of your cheek cells. Are they all the same shape?

32. In what ways do check cells differ from *Elodea* cells?

33. Why did you use methylene blue in this experiment?

34. Do you see any chloroplasts in your cheek cells? Why or why not?

D. Swab the fleshy part of your fingertip with an alcohol swab. Prick yourself with a sterile lancet, and place a drop of blood on a clean slide. Alternatively, you may use the blood provided by your instructor. Add a coverslip, and observe the slide under low power of your microscope. When you have located a good field of view, switch to high power.

35. In the space provided below, draw two or three cells. Label any cell parts that you can identify.

36. How does the outer edge of a blood cell compare with that of a cheek cell?

37. Describe the shape of blood cells. Are they all the same shape? Why or why not?

38. In what structural ways do blood cells differ from check cells?

39. Can you see any structural advantages in the way your blood cells are shaped? How is this connected with the function of blood cells in your body?

40. Why did you not use methylene blue in this experiment?

Resources

American Cancer Society. *The Cell, Structure and Function.* 15 overhead transparencies. Available from local American Cancer Society chapters.

Inside the Cell: Microstructures, Mechanisms, and Molecules. 2 carousel slide trays and cassettes, 1979.

The Living Cell, CQ5-3150, 4 filmstrips and cassettes, consisting of *The Basis of Life* (CQ5-3151), *One-celled Organisms* (CQ5-3152), *The Cells of Plants* (CQ5-3153), and *The Cells of Animals* (CQ5-3154), 1980.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- cell membrane
- cell wall
- chloroplast
- electron microscope
- eukaryote
- leucoplast
- micron (μ)
- nucleus
- organelle
- plastid
- prokaryote
- vacuole
- vital stain

Review
9. Cells

Name______________________________

Date_______________________________

Multiple choice

______ 1. The green pigmented structures found in most plant cells are
- a. chromophyll
- b. chlorophyll
- c. leucoplasts
- d. chloroplasts

______ 2. Cell walls are not found in
- a. plant cells
- b. bacterial cells
- c. *Elodea* cells
- d. animal cells

______ 3. Cytoplasmic streaming (movement) occurs in
- a. *Elodea* cells
- b. potato cells
- c. cheek cells
- d. blood cells

______ 4. A micron is
- a. one hundredth of a meter
- b. one thousandth of a meter
- c. one ten thousandth of a meter
- d. one millionth of a meter

______ 5. The stain which causes certain plant nuclei to turn a dark yellow or brown color is
- a. methylene blue
- b. Benedict's solution
- c. iodine
- d. ninhydrin

______ 6. Methylene blue dye was used to stain the
- a. onion cells
- b. cheek cells
- c. *Elodea* cells
- d. potato cells

______ 7. The basic unit of life is the
- a. organelle
- b. virus
- c. cell
- d. electron

______ 8. Robert Hooke is credited with the discovery of the
- a. nucleus
- b. cell
- c. cytoplasm
- d. ribosome

______ 9. Student A observed a cell under the microscope. He identified it as a plant cell and not an animal cell because he noted the presence of
- a. a nucleus
- b. a cell wall
- c. a cell membrane
- d. ribosomes

______ 10. Most cells lacking a cell wall would also lack a
- a. mitochondria
- b. chloroplast
- c. cell membrane
- d. vacuole

______ 11. A limitation of the electron microscope is that it
a. has poor resolution
b. uses short wave electrons
c. cannot magnify about 1000X
d. cannot be used to study live specimens

______ 12. Which of the following cells have no nucleus?
a. cheek
b. blood
c. *Elodea*
d. potato

______ 13. Which of the following cells have large starch storage organelles?
a. cheek
b. blood
c. *Elodea*
d. potato

______ 14. Which of the following have the largest vacuoles?
a. cheek
b. blood
c. *Elodea*
d. potato

______ 15. Eukaryotic cells are also known as
a. true cells
b. bacterial cells
c. prokaryotic cells
d. the only living cells

10. Laboratory

Cell Membrane Diffusion

When you have completed this laboratory you should be able to:

1. Define the terms diffusion, concentration gradient, active transport, net diffusion, dialysis, and facilitated diffusion.
2. Demonstrate the functioning of a semi-permeable membrane.

Diffusion

Diffusion is the movement of solute and solvent particles in all directions through a solution, or, in both directions through a membrane. The term solute refers to molecules dissolved in a solvent. In this experiment, glucose and starch molecules will be the solutes, and they will be dissolved in the solvent water.

Diffusion moves solute through a solvent until the solute is well mixed. This passive mechanism is driven by differences in the concentration gradient, or molecular movement from areas of higher concentration to lower concentration. Diffusion occurs naturally within the atmosphere, lakes and ponds, and across cell membranes. Diffusion is different from another way organisms move materials. This other way is called active transport. It is the movement of a substance through a membrane against, or in opposition to, the concentration gradient. In active transport the organism actively seeks and moves the substance it needs across the cell membrane.

Net Diffusion

Net diffusion is the movement of more particles of a substance in one direction than in the opposite direction. The net diffusion of any substance occurs down its own concentration gradient. Therefore, the net diffusion of solute particles occurs from more concentrated to less concentrated areas, and the net diffusion of water molecules, in contrast, occurs from the more dilute to the less dilute.

Dialysis

Dialysis is diffusion under certain conditions. It takes place when a solution contains both crystalloids, or solute particles whose diameters are very small, such as glucose and oxygen, and colloids, or solute particles whose diameters are relatively large, such as starch and proteins. When this solution is separated from plain water by a membrane permeable to small diameter crystalloids, but impermeable to larger diameter colloids, the crystalloids diffuse through the membrane and the colloids remain behind. Therefore, dialysis can be defined as a form of diffusion which separates crystalloids from colloids. Human kidney dialysis machines operate upon this principle. This laboratory actually is a demonstration of this special type of diffusion.

Facilitated Diffusion

Facilitated diffusion resembles both ordinary diffusion and active transport. It is a passive process in that a substance moves down its own concentration gradient. However, like active transport, facilitated diffusion also is assisted by an outside force. The active agent is a carrier molecule, such as a specific protein on the outer surface of a cell membrane, which binds to the substance to be carried through the membrane. The bound carrier molecule rotates within the membrane and thereby carries the substance rapidly from one side of the membrane to the other. There it dissociates from the substance, releasing it into the cytoplasm of the cell. The carrier molecule has thereby facilitated, or helped the substance through the cell membrane.

This laboratory is designed to help you understand how materials move in and out of cells. You will construct a model of a cell membrane in order to study the movement of water, glucose, and starch through cell membranes.

Pre-lab

Supplies needed:

Equipment

- 2 500 ml. beakers
- eye dropper
- glass rod
- ring stand with clamps
- 2 test tubes

Materials

- starch suspension
- glucose solution
- dialysis tubing
- distilled water
- goggles
- Benedict's solution
- iodine solution
- string
- matches or striker
- protective apron

Special Preparations

1) Starch solution: dissolve cornstarch in water and heat to boiling, stirring gently. The amounts do not need to be exact. One large spoonful in 1 liter water is adequate for several classes.

2) Glucose solution: dissolve two or three spoonfuls of glucose (dextrose) in 1 liter water and stir until fully dissolved. You can also use Karo syrup as a glucose source.

3) Iodine solution: dissolve 10 g. potassium iodide and 3 g. iodine in 1 liter water. Store in a brown bottle or in a dark room.

4) Benedict's solution: dissolve 173 g. sodium citrate and 100 g. sodium carbonate in 700 ml. water, stirring and heating the solution. Filter the product. Dissolve 17.3 g. copper sulfate in 100 ml. water. **Slowly** add the copper sulfate solution to the first solution. Then add water to reach a total volume of 1 liter.

5) Dialysis tubing: 1.5 cm. wide. Cut the cellophane dialysis tubing so that each student group will have a 20 cm. long section.

6) Provide a ball of string and a pair of scissors for the class. Students may cut two lengths sufficient to tie off the two ends of the dialysis tubing.

7) Provide 2 liters distilled water per class.

8) It is most convenient to have the iodine and Benedict's solutions available in dropper bottles, one set per laboratory group.

Time Required

The cell membrane diffusion laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Step

A. Soak a 20 cm. section of cellophane dialysis tubing in water for five minutes. Then gently rub the ends between your thumb and index finger until the ends separate. Carefully push a glass rod through the opening in order to hold the tube open. Twist one end of the tubing and tie it tightly with string. Remove the glass rod and fill this dialysis bag approximately half with starch suspension and half with sugar solution. Tie the top of the bag with string, leaving a loose piece of string 10 to 15 cm. long. Thoroughly rinse the bag with distilled water.

1. Why is it important to rinse the bag with water?

B. Place the bag in a beaker of distilled water. Leave the loose piece of string outside the beaker so that you may later use it to remove the bag from the water. Wait fifteen to twenty minutes, performing step C during the interim.

C. Put on your goggles and apron. Set up a boiling water bath by lighting a bunsen burner and placing it under a ring stand upon which you have placed a beaker half filled with water.

D. After fifteen to twenty minutes remove a dropperful of water from the beaker in which you have been soaking the dialysis bag filled with starch suspension and sugar solution. Place this water in a test tube and add 10 drops of Benedict's solution. Heat the test tube in the boiling water bath for five to ten minutes.

2. What are you testing for (refer to laboratory 5)?
3. Initially what is the color of the water and Benedict's solution mixture in the test tube?
4. What is the color of the water and Benedict's solution mixture after being heated in the boiling water bath?
5. Explain what your answers to questions three and four indicate.

E. Remove another dropperful of water from the beaker in which you have been soaking the dialysis bag filled with starch suspension and sugar solution. Place this water in a test tube, and add 3 drops of iodine solution. Observe the color of the water after the iodine has been added.

6. What changes, if any, do you observe?
7. If a change has occurred, what does this indicate (refer to laboratory 5)?
8. Compare the size of a glucose molecule and a starch molecule (refer to exercise 4). How does this size difference affect the results you encountered in this laboratory?

9. What evidence, if any, did you find which indicates that the cellophane dialysis bag was semi-permeable?

10. Did diffusion take place in this laboratory? If so, what type of diffusion?

Resources

Biology Media. *Membranes*. EP 2075, 1 carousel tray, cassette and guide.

Lodish, Harvey F., and James E. Rothman. "The Assembly of Cell Membranes," *Scientific American*, January 1979.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- active transport
- colloid
- concentration gradient
- crystalloid
- dialysis
- diffusion
- facilitated diffusion
- net diffusion
- semi-permeable membrane
- solute
- solvent

Review

10. Cell Membrane Diffusion

Name______________________________

Date______________________________

Matching: choose the best answer

______ 1. active transport

______ 2. facilitated diffusion

______ 3. crystalloid

______ 4. colloid

______ 5. Benedict's solution

______ 6. iodine solution

______ 7. net diffusion

______ 8. dialysis

______ 9. solute

______ 10. solvent

A. It is dissolved in water.

B. It turns blue-black in the presence of starch.

C. It turns orange-red in the presence of sugar.

D. It moves against a concentration.

E. It moves with the aid of a carrier molecule.

F. It moves crystalloids but not colloids.

G. It dissolves glucose into solution.

H. It is a small molecule.

I. It passively moves molecules one way to reach equilibrium.

J. It is a relatively large molecule.

11. Station Laboratory

Food and Respiration

When you have completed this laboratory you should be able to:

1. Describe how respiration helps man prepare food, drink, and textiles for use.
2. Explain how microorganisms are used to make, preserve, and/or enhance the flavor of foods.
3. Understand the processes of respiration and fermentation.

Respiration and Fermentation

The processes of respiration and fermentation have been exploited by man to prepare food, drink, and textiles for human use since pre-historic times. Respiration is the energy-yielding process of living organisms. It requires oxygen, while fermentation is its counterpart, which occurs in the absence of oxygen. The energy yielded from fermentation is not as great as that from respiration. Although used by man since ancient times, it has only been in recent times that the microbiological processes which occur in the production of beer and wine, the leavening of bread, the making of vinegar and cheese, and the retting of flax have been understood.

Many different types of microorganisms aid in man's efforts to preserve or enhance the flavor of foods. Yeast is the most commonly used, being a fungus which, because of its rapid growth, produces marked changes in the foods to which it has been added. Yeast is a facultative anaerobe, which means that it can respire and grow either in the presence of oxygen, aerobically (producing carbon dioxide), or without oxygen, anaerobically (producing lactic acid or alcohol). Bread is leavened with yeast growing both aerobically and anaerobically. The carbon dioxide by-product of yeast feeding and growing on dough causes the bread to rise. Bread dough also contains some alcohol, which is driven off during baking. The longer bread dough is allowed to rise before baking, the more alcohol it will contain. Alcoholic beverages, on the other hand, result from yeast growing strictly anaerobically.

The manufacture and consumption of alcoholic beverages is noted in the oldest records of man. This use of anaerobic respiration, or fermentation, of microorganisms goes back to man's beginnings. By placing fruit or vegetable juices, or grain infusions, which had been contaminated by wild yeasts and bacteria into containers, ancient man was able to create an airless environment which promoted the fermentation of organisms in the juices. If this is done with grape juice, wine results. If done with a mash made from primarily grains and water, beer results.

Today you will observe several different situations in which respiration and fermentation are utilized to make a food product. You will draw conclusions from your observations.

Pre-lab

Supplies needed:

Equipment

1-2 liter soda bottle with cap
tuna fish can, or similar can
plastic fork
glass jar

Materials

masking tape
rubber band
small paper plate
cheesecloth
marking pen

Special Preparations

1) Students may supply their own clean soda bottle, tuna fish can, and glass jar. The tuna fish can (or cat food can) must have both the top and bottom lids removed so that it forms a ring. There must not be any sharp edges on the can. The glass jar may be of any shape or size, such as a used pickle jar.

2) As this is a station laboratory, the instructor or a designated group of students needs to set up and supply the following laboratory stations. Necessary materials and equipment are indicated for each station. Label each station with the appropriate number. Make certain that all materials and equipment are absolutely clean, because students will be asked to taste different food products during this laboratory.

Station 1: obtain a large pot. Make root beer in this pot by mixing a bottle of root beer extract, yeast, sugar, and water per the directions on the root beer extract bottle. Leave the root beer extract bottle nearby so that students may read for themselves the exact proportions for making root beer. Provide ladles and funnels for students to transfer the liquid into their soda bottles.

Station 2: provide two large bowls. Fill one with chopped cabbage, and the other with sauerkraut.

Station 3: provide one simple biscuit made with baking powder (or baking soda) for each laboratory group to taste.

Plug in a large electric skillet. Provide butter or margarine, pastry brush, paper toweling, a thermometer, and a spatula. Make a yeast batter for crumpets using the following recipe. Each recipe makes seven or eight crumpets. Allow one crumpet per laboratory group.

1 package dry yeast
1 teaspoon sugar
1/4 cup warm water
1/3 cup milk
1 egg
1 tablespoon butter or margarine
1 cup flour
1/2 teaspoon salt

Combine yeast, sugar and warm water in a large bowl; let it stand until bubbly (about 15 minutes). Blend in milk, egg, and butter. Add flour and salt and beat until smooth. Cover and let stand in a warm place until almost doubled in size (about one hour).

Station 4: provide a large pot filled with water to which has been added apple peels and cores and one cup sugar per gallon water. Bring this mixture to a boil, and when it has returned to room temperature, add one-half package dry yeast per gallon water. (Apple peels and cores can be saved over a period of time; whenever you peel or core an apple, put the peel or core in a plastic bag in the freezer, thus adding to the bag when you can).

Station 5: provide samples of flax and/or linen.

3) Some of the stations require that students set up their own fermentation laboratory experiment and then, after several days or weeks, determine the results. The results of these experiments are easily incorporated into classroom discussions at that time.

Time Required

The food and respiration laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Stations

Students will spend equal amounts of time at each of five stations, performing experiments and/or answering questions about each station in turn. Some of the stations require preparation of material to be fermented and tested at a later date.

Station 1: Root Beer

Root beer mix contains yeast, sugar, root beer extract, and water. Each laboratory group will fill one soda bottle with the root beer mix provided. Cap the bottle tightly and label it, using masking tape marked with your names, class, and today's date. This bottle is to be stored for one to two weeks until the yeast has acted upon the sugar and produced carbon dioxide in sufficient amounts to carbonate the drink (do not store too long, or pressure build-up may cause the bottle to explode). Chill and serve.

1. What food does the yeast use to grow, or respire? ______________________________

2. Why is it important to make certain that the cap of the bottle is screwed on tightly? ______________

   ____

   ____

3. Why is fermentation time approximate (one to two weeks)? List the variable factors which can affect the time required for fermentation.

   ____

   ____

   ____

   ____

4. In what other way can you introduce carbonation to a drink? ______________________

   ____

   ____

5. What might be produced by the yeast, besides carbon dioxide, as the oxygen supply is depleted inside the capped bottle?

   ____

Station 2: Pickles and Sauerkraut

Certain lactic acid bacteria are found characteristically on plant materials, and these organisms are responsible for the souring processes which occur during the preparation of pickles and sauerkraut. These bacteria produce lactic acid, which imparts a sour flavor, as they ferment. Lactic acid in sufficient quantity prevents contamination and decay of the food by other harmful microorganisms.

This same process occurs when green fodder is placed in silos and also during the fermentation of molasses and cane sugar. The polysaccharide residue of molasses with cane sugar fermentation is known as dextran, and it has been discovered that dextran can be used as a substitute for blood plasma. Dextran now is in great demand industrially.

To make sauerkraut yourself, simply mix chopped cabbage and salt, place in a container (preferably glass or stoneware), press everything to the bottom, and weigh down with a plate and rock (or a jar filled with water). Fermentation time will depend upon temperature. Check periodically until the cabbage has soured to the flavor you prefer.

6. What do the lactic acid bacteria eat when they ferment (anaerobically) on plants (taste both the cabbage and the sauerkraut)?

7. Compare lactic acid bacteria with other types of food preservatives.

8. Taste the flavor of both the fresh cabbage and the sauerkraut. Do the lactic acid bacteria achieve only a souring of the cabbage, or are there other flavor changes as well? Why?

9. Name five other major food products that are soured or fermented.

10. Name a cheese with internal holes which result from the release of carbon dioxide as a by-product of respiration during production of the cheese.

Station 3: Bread

The use of yeasts to leaven bread seems to have been known at least 6,000 years ago in Egypt and to have spread eventually across the face of the globe. Alcoholic fermentation by yeast is essential to the production of most types of bread. Excepting unleavened flat breads, carbon dioxide produced during fermentation of the dough by yeast causes the bread to rise.

At this station you should see a frying pan and batter. The batter is composed of flour, yeast, salt, sugar, milk, water, and eggs. Each laboratory group will determine the temperature of the frying pan at this station, and record it in question eleven below. You will then lightly butter the pan and place a greased metal ring on the pan. The ring, of course, was made from a tin can. Pour two to three tablespoons of batter into the ring and observe the results. In approximately seven minutes of cooking the batter will have risen; remove the ring and turn the batter over with the spatula provided. Allow the batter to cook for another two or three minutes. Sample your product. Also sample the biscuit provided. They are best with butter.

11. What was the temperature of the pan? __________

12. What bread product is this? __________

13. What causes the carbon dioxide to be trapped in the dough and used as a leavening agent, rather than simply escaping as gas into the air?

14. What does the yeast use as food? ______________________________

15. Does bread made with baking powder or baking soda (quick breads) taste similar to yeast breads? Why or why not?

____

____

____

____

____

16. Can you conclude that the fermentation of yeast with flour causes flavor changes in the flour? Why or why not?

____

____

____

____

____

Station 4: Vinegar

Wine or beer openly exposed to the air often turns sour. This souring is caused by the oxidation of the alcohol to acetic acid, as expressed by the following empirical equation:

$$CH_3CH_2OH + O_2 \longrightarrow CH_3COOH + H_2O$$

This reaction is triggered by a special group of bacteria, the acetic acid bacteria. The conversion process is strictly aerobic respiration. Certain acetic acid bacteria are known as over-oxidizers, and they can further oxidize acetic acid to CO_2 and H_2O. Therefore, food processors must monitor the reaction carefully.

Note the liquid in the pot. It is a mixture of water, yeast, sugar, and apple peels and cores. Fill a glass jar three quarters full of the liquid portion of the mixture in the pot, and cover the jar with cheesecloth attached by a rubber band (thereby providing an aerobic condition). Label your jar with your names, class, and today's date. This jar should now be stored for three to five weeks. At that time, check for the production of vinegar.

17. Write the empirical equation for the over-oxidation of acetic acid in the space provided below.

18. Why is the length of time required for the respiration of the liquid from the apple residue pot variable? List three factors.

____

____

____

____

19. What do the yeast and bacteria use as food? ______________________________

20. Why would the addition of yeast promote the growth of acetic acid bacteria?

Station 5: Textiles

Retting can be defined as the controlled microbial decomposition of plant materials so as to separate certain components of the plant tissue. The oldest retting process, used by the human race for thousands of years, is the retting of flax and hemp in order to free fibers to be used to make linen. These fibers, composed of polysaccharide cellulose, are held together in the plant stem by pectin. Retting decomposes the pectin.

The plants are soaked in water, and microbial development begins. At first the organisms that multiply are primarily aerobes which consume oxygen dissolved in the water. Next a vigorous development of anaerobic butyric acid bacteria begins. If the retting process continues too long, cellulose-fermenting bacteria will also develop and destroy the flax fibers as well, so the process must be terminated at the right time.

Certain groups of butyric acid bacteria (*Clostridium acetobutylicum*) are utilized commercially today to produce the industrial chemicals acetone and butenol.

21. Butyric acid bacteria are easily contaminated. *Clostridium botulinus* is another anerobic bacterium closely related to *Clostridium acetobutylicum*. Can you guess from the name, *C. botulinus*, the problems caused by this fermenting relative of *C. acetobutylicum*? Discuss.

22. If the cellulose fermenting bacteria are allowed to grow, what would be the resulting material?

23. Can you think of two substances used in food production which would inhibit the growth of cellulose fermenting bacteria? Name them.

Summary:

24. Define the terms aerobes, anaerobes, and facultative anaerobes.

25. Name the aerobes, anaerobes, and facultative anaerobes discussed in this laboratory. ________________

26. Define the terms respiration and fermentation. ________________

27. List food types which are fermented as a method of preservation, and/or for flavor enhancement.

28. Explain the relationship between respiring microorganisms in the production and preservation of food. Consider in your answer the making of vinegar and textiles.

29. Why is there a flavor difference between regular yeast breads and sour dough breads? What other form of microorganism might be growing in sour dough cultures?

Resources

Apple Computer. *Advanced Cell Respiration*. C4077, computer program containing 4 tutorials, separate test disk, student study sheets, and teacher's guide. 1985.

Biology Media. *Respiration*. EP2077, slide carousel tray, cassette, and guide.

Rose, Anthony H. "The Microbiological Production of Food and Drink," *Scientific American*, March 1981.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- aerobic
- anaerobic
- facultative anaerobe
- fermentation
- respiration
- retting

Review

11. Food and Respiration

Name______________________________

Date______________________________

Multiple choice

______ 1. The most important aspect of cellular respiration is the release of
a. glucose
b. enzymes
c. lactic acid
d. energy

______ 2. Fermentation is
a. a type of photosynthesis
b. totally aerobic
c. totally anaerobic
d. more efficient than respiration

______ 3. In the making of root beer and bread, yeast use
a. sugar for food
b. carbon dioxide for food
c. alcohol for food
d. flour for food

______ 4. Bread rises because
a. the yeast grow
b. carbon dioxide is trapped
c. the flour expands
d. the temperature is hot

______ 5. Facultative anaerobes
a. must have oxygen
b. must have alcohol
c. function with or without oxygen
d. function only without oxygen

______ 6. The stage where oxygen is used in respiration is called
a. aerobic
b. anaerobic
c. lactic acidic
d. acetic acidic

______ 7. The primary waste product of respiration is
a. glucose
b. ATP
c. carbon dioxide
d. oxygen

______ 8. Retting refers to a process in the making of
a. sauerkraut
b. cloth
c. root beer
d. bread

______ 9. Acetic acid bacteria are strictly
a. aerobes
b. reducers
c. anaerobes
d. facultative anaerobes

______ 10. The delicious sour flavor of dill pickles is produced by
a. lactic acid bacteria
b. acetic acid bacteria
c. butyric acid bacteria
d. yeast

12. Laboratory

Leaf Pigment Separation

When you have completed this laboratory you should be able to:

1. Understand the techniques of paper chromatography.
2. Determine experimentally whether chlorophyll is one pigment or composed of several different pigments.

Chromatography

Mixtures of chemical substances can be separated by many techniques. One of these, chromatography, is a very simple but elegant analytical technique. A drop of a solution containing a mixture of chemicals to be separated is placed near one end of a strip of filter paper. The paper is then lowered into a container containing appropriate solvents until the end of the paper is covered by the solvent. The solvent works its way up the paper by capillary action. As the solvent climbs the paper strip in a candlewicking effect, it also carries the mixture of chemicals to be separated. The chemicals move up the strip relative to their dissolvability in the solvent as well as relative to their respective molecular weights. Chemicals in a given material always travel the same relative distances when undergoing chromatographic separation. When a mixture of pigments has undergone paper chromatographic separation, distinct lines or dots can be seen on the paper strip.

Chlorophyll

Photosynthesizing plants contain chlorophyll, the key to photosynthesis. Many plants contain this pigment in an organelle called the chloroplast. Many plants also contain other pigments, such as carotenoids (first discovered in carrots) and phycobilins (discovered in algae), but although these other pigments enhance the action of chlorophyll, they cannot photosynthesize by themselves. Actually we know today that there are at least seven different types of chlorophyll called chlorophylls *a*, *b*, *c*, *d*, and *e*, bacteriochlorophyll, and bacterioviridin.

In this laboratory you will determine if the chlorophyll present in fresh spinach leaves is one pigment, or if it is composed of several different pigments. You also will determine how many materials are present in the ink of a marking pen.

Pre-lab

Supplies needed:

Equipment

2 300 ml. beakers
10 ml. graduated cylinder
100 ml. graduated cylinder
mortar and pestle
small paint brush
metric rules

Materials

spinach leaf
4 filter paper strips
10 ml. acetone
4 paper clips
felt marking pen
sand
100 ml. methyl alcohol

Special Preparations

1) The spinach must be fresh.

2) The filter paper strips should be of uniform size. Two centimeters wide by ten centimeters in length is a good workable size. Cut the strips before the beginning of the laboratory.

3) It is interesting to provide several different brands of felt markers, because students will obtain different results with different types. All markers should have a fine tip.

Time Required

The leaf pigment separation laboratory requires one laboratory hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Obtain two filter paper strips, two paper clips, a 300 ml. beaker, and a felt marking pen. Add tap water to the beaker to a level of approximately one centimeter in depth. At one and one half centimeters from one end of both filter paper strips, carefully draw a line parallel to the bottom of the paper strip. Lower the strip into the beaker, taking care not to wet the line made by the pen. Stand each strip in the beaker by taking the paper clip and bending it, so that one piece of wire goes through the upper end of the paper strip and the rest of the clip is hooked over the edge of the beaker. The bottom of each paper strip should now be in water, and the rest of the strip should rise straight out of the water. Leave this set-up for fifteen or twenty minutes while you proceed with steps B, C, D, and E.

1. What is the brand name of the marker used in step A? ______________________________

B. Obtain a fresh spinach leaf, a mortar and pestle with a little sand in the bottom of the mortar, a small paint brush, 10 ml. acetone, two filter paper strips, two paper clips, another 300 ml. beaker, and 100 ml. methyl alcohol. Prepare a chlorophyll extract of spinach by grinding the leaf in the mortar and pestle to which you have also added 10 ml. acetone. The sand helps to pulverize the leaf, and the acetone aids in the disintegration of the chloroplasts and subsequent release of the chlorophyll inside.

C. Apply by paint brush a narrow strip of chlorophyll extract to two filter paper strips one and one half centimeters from the bottom end of each strip. Try to make the chlorophyll line no wider than that which you applied with the marking pen in step A. Thoroughly dry the paper strips by blowing on the strips, or by waving them in the air.

D. Repeat step C five more times, using the same filter strips and placing more chlorophyll extract on the same line. Remember to dry the strips between each application of chlorophyll extract.

E. Pour 100 ml. methyl alcohol in the bottom of a 300 ml. beaker. Carefully place the two filter paper strips with chlorophyll extract lines in the beaker in the same manner as you positioned the filter paper strips in step A. You will lower the strip into the beaker, taking care not to wet the line made by the extract and stand each strip in the beaker by taking a paper clip and bending it, so that one piece of wire goes through the upper end of the paper strip and the rest of the clip is hooked over the edge of the beaker. The bottom of each paper strip should now be in water, and the rest of the strip should rise straight out of the water. Leave this set-up for fifteen or twenty minutes.

F. Examine the set-up from step A. Remove the filter paper strips and dry them. Number the distinct dots on each filter paper strip, and staple both strips to the top of this page. If you are working in a laboratory group write the names of your partners in the space provided below. They thus may also receive credit for having produced strips.

____

____

____

____

2. How many dots of pigment were on each filter paper strip? ______________

3. Were the number of dots on both strips the same? Why or why not? ______________

____

____

____

4. Are the dots the same color? Why or why not? ______________

____

____

____

5. What do the dots on the strips represent? ______________

____

____

____

6. Why do you think you used water to dissolve the ink but not the chlorophyll? ______________

____

____

____

G. Examine the set-up from step E. Remove the filter paper strips and dry them. Number the distinct dots on each filter paper strip, and staple both strips to the top of this page.

7. How many dots of pigment were on each filter paper strip? ______________

8. Were there the same number of dots on both strips? Why or why not? ______________

____

____

____

9. Are the dots the same color? Why or why not? ______________

____

____

____

10. What do the dots on the strips represent?

11. If the green color of spinach results from more than one pigment, why are all of the pigments not visible to the eye?

12. Offer a reason why some leaves change color in the fall.

13. Devise an experiment to show that chlorophyll is the pigment responsible for photosynthesis. Use the paper chromatography strips you obtained during the course of this laboratory in your hypothetical discussion.

Resources

Apple. *Advanced Photosynthesis.* C 4079, four computer tutorials, separate test disk, student study sheets, and teacher's guide, 1985.

Biology Media. *Photosynthesis.* EP 2078, slides in carousel tray, cassette, and guide.

Carolina Biological. *Photosynthesis: The Flow of Energy from Sun to Man Set.* 48-2475, slides in carousel tray and cassette.

Films for the Humanities. "An investigation of Photosynthesis and Assimilate Transport." *Experiment: Biology Series.* Video cassette #FFH 1087D for VHS, Beta, or U-Matic. Princeton, New Jersey.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

chlorophyll
paper chromatography

Review

12. Leaf Pigment Separation

Name______________________________

Date_______________________________

Essay

1. Describe paper chromatographic techniques. What are the advantages of such a technique?

2. Discuss the importance of chlorophyll in photosynthesis, its location, and its component parts.

13. Exercise

DNA Models

When you have completed this exercise you should be able to:

1. Understand the basic structure of DNA and RNA molecules.
2. Construct a DNA molecule model.
3. Identify and label the molecular structure of DNA and RNA.

James Watson and Francis Crick

DNA molecular structure was determined primarily by two scientists, the American James Watson and the Englishman Francis Crick. Watson went to Cambridge, England in the early 1950's as a young scientist on a research fellowship to study structures of biological molecules. There he met Francis Crick. They were both interested in DNA, and they joined forces to solve the problem of its molecular structure. They did not do experiments in the traditional sense, but rather they examined all available data on DNA and attempted to synthesize available data into a logical whole. For their efforts they won the Nobel Prize. Today every secondary school biology student learns about the work of Watson and Crick, as you will in this exercise.

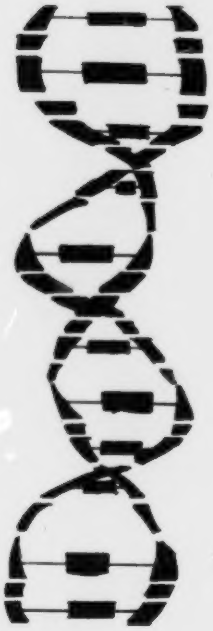
DNA and RNA

The DNA, or deoxyribonucleic acid, molecule is shaped like a ladder of many rungs which has been twisted into a spiral. The sides of the "ladder" are composed of alternating units of a five carbon deoxyribose sugar and a phosphate. RNA, or ribonucleic acid, has the same spiraling ladder structure, but it is single stranded, or, phrased differently, it has only one side in its "ladder." Also, the sugar in RNA's single "side" is a ribose sugar, with one more oxygen atom than that found in deoxyribose ("de" means deprived).

The rungs of the "ladder" are composed of special proteins called "bases." These bases on the "rungs," together with a deoxyribose sugar and a phosphate from the "side," constitute a nucleotide. Any given DNA or RNA molecule is composed of many such nucleotide units. The compounds on the rungs are called nitrogenous bases because they are proteins which measure as basic with a pH test. See figure one for an illustration of a small section of a double helix DNA molecule.

There are four types of bases in DNA. Two of the bases are purines. The purines are adenine and guanine. They consist of a double ring which totals nine nitrogen and carbon atoms in the rings, to which hydrogen, oxygen, and other nitrogen atoms are attached. The other two bases are pyrimidines called thymine and cytosine. In RNA, or ribonucleic acid, the pyrimidine uracil takes the place of thymine. The pyrimidine bases consist of a single six atom ring of carbon and nitrogen to which hydrogen, oxygen, and other nitrogen atoms are attached. The bases are denoted by their first letters, A, G, T, C, and U.

These bases always bond in a certain way. One part bonds to the sugar-phosphate complex on the side of the ladder to form the nucleotide unit. Another part of the base bonds only with particular bases to complete the rungs of the ladder in a DNA molecule. Adenine bonds only to thymine, and vice versa, and similarly cytosine and guanine only bond to each other. In RNA, uracil substitutes for thymine.



DNA

Figure 1

DNA molecules are very long and are contained in the nucleus of every eukaryotic cell. Each DNA molecule contains a huge set of messages that direct how a cell functions and how it reproduces. DNA transmits these messages as they are needed via mRNA molecules. These mRNA (messenger RNA) molecules are produced in the nucleus by duplicating the appropriate section of one side of the DNA. These mRNA molecules are small enough to travel through the nuclear membrane to the cytoplasm of the cell, where they attach to a ribosome. A mRNA attached to a ribosome in the cytoplasm directs the order in which amino acids, carried by tRNA (transfer RNA) are joined. Ribosomal RNA (rRNA) molecules are thought to help in the attachment of mRNA to the ribosome. This entire, extremely complex, process is called protein synthesis.

DNA Models

In this exercise you will construct a three dimensional DNA model. This model will enable you to envision the structure of the DNA molecule. Your instructor will set the exact date when the model is due, and you will be guided by the following basic rules.

1) Materials: you may make your model out of anything. Suggestions include such materials as toothpicks, candy, pastries, wire, wood, buttons, coathangers, clay, straws, metal, plastic, pipecleaners, and construction paper. The size of your model also is left to your imagination and your ability to transport it intact to the classroom. Do not forget, it must be durable enough to stay in one piece for teacher evaluation.

2) Structure: you must design your model so that it is a faithful representation of a DNA molecule. The sugar and phosphate sides of the "ladder" must be shown in correct sequence, as well as the bases on the rungs in their relationships to each other. The "ladder" also must be twisted into a double helix, or spiral.

3) Labels: although you may use any materials to represent the building blocks of the DNA molecule, you must attach a key to the bottom of the model which explains what each material or color represents. This key may be color coded, or coded by shape, or coded by object, depending upon what you use. Put your name, class, and date on the DNA model.

Date Due: ____________

Review

1. What is the general structure of DNA?
2. The sides of a DNA "ladder" are composed of what compounds?
3. What is the basic unit of DNA, and of what is it composed?
4. What are the purine bases of DNA?
5. What are the pyrimidine bases of DNA?
6. What takes the place of the thymine base in RNA?
7. In what sequence do these bases bond together?
8. Explain the origin and destination of mRNA.
9. Explain the function of tRNA in protein synthesis.

10. How do cell ribosomes function in protein synthesis?

11. What is rRNA?

12. Name three structural differences between DNA and RNA.

Resources

Bell Telephone. *The Thread of Life*, parts I & II. Film.

Biology Media. *The Chemistry of Nucleic Acids*. EP 2068, slides in carousel tray, cassette, and guide.

Coniff, Richard. "Supergene," *Science Digest*, 90(3), 1982.

Encyclopedia Britannica. "DNA, Molecules of Heredity." Film #1826 in the series *Heredity and Adaptive Change*.

Newsweek. "The Miracles of Spliced Genes," *Newsweek*, March 17, 1980.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

adenine
base
cytosine
deoxyribonucleic acid
guanine
messenger RNA
nucleotide
protein synthesis
purine
pyrimidine
ribonucleic acid
ribose
thymine
transfer RNA
uracil

Review
13. DNA Models

Name ____________________

Date ____________________

Matching

______ 1. deoxyribonucleic acid

______ 2. uracil

______ 3. protein synthesis

______ 4. ribose

______ 5. adenine and guanine

______ 6. thymine and cytosine

______ 7. nucleotide

______ 8. ribonucleic acid

______ 9. mRNA

______ 10. tRNA

A. a base substitute for thymine in RNA

B. RNA

C. DNA

D. a sugar

E. purine base

F. pyrimidine base

G. made in the nucleus, travels to ribosomes

H. found in the cytoplasm, carries amino acids

I. unit consisting of a sugar, a phosphate, and a base

J. making proteins chemically

Essay

1. Describe the structure and shape of a DNA molecule. ____________________

2. Explain the process of protein systhesis in the cell. ________________________________

14. Exercise

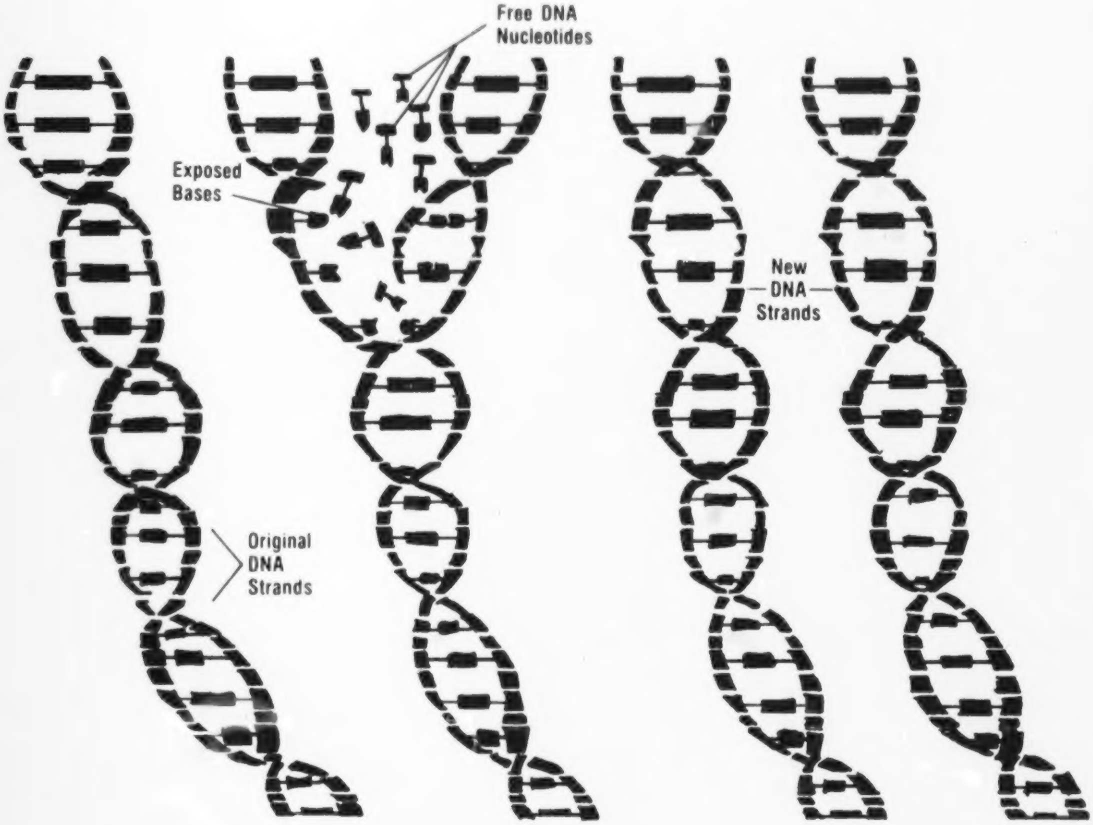
Phases of Mitosis and Meiosis

When you have completed this exercise you should be able to:

1. Understand the processes of mitosis and meiosis.
2. Describe and diagram the phases of mitosis and meiosis in both plant and animal cells.
3. Relate DNA replication and mitosis/meiosis to reproduction.

Mitosis

Before a cell divides, all the DNA in the cell replicates, forming two sets of identical strands. This process has been described as an unzipping in which the DNA molecule splits down the middle and then replaces the other half with complimentary nucleotides floating within the cell. See figure one which illustrates this unzipping and duplicating process.



DNA Replication
Figure 1

DNA molecules typically are several meters in length, if uncoiled, and carry hereditary traits on individual sections called genes. When these long DNA strands clump around a protein core, they become visible with a simple microscope and are known as chromosomes. Formation and then distribution of duplicate chromosomes to daughter nuclei assure the formation of genetically identical daughter cells.

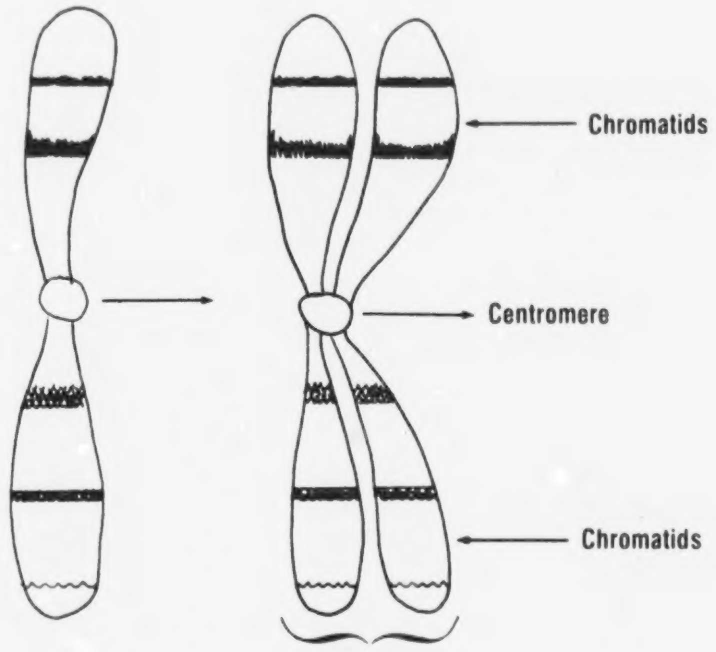
Mitosis is a type of cell division resulting in two identical daughter cells. It is a continuous process, but, for ease of understanding, the process can be considered as consisting of five phases, interphase, prophase, metaphase, anaphase, and telophase. Although these phases are not separated by abrupt changes, certain significant events distinguish each part of the process. Mitosis in an animal cell is explained in the following paragraphs in terms of these phases.

Interphase

Interphase is not a part of mitosis, but it is the stage in the life of a cell between nuclear divisions. During interphase, the cell is in a period of growth and other activities, such as the transcription of RNA by DNA. The DNA look like fine threads spread throughout the nucleus, and the nuclear membrane is present. Near the end of this period, the DNA replicate and begin to form thickened chromosomes. The centrosome, which lies just outside the nuclear membrane, also divides in preparation for the coming nuclear division.

Prophase

Prophase marks the first clear signs that mitotic division is beginning. The centrosomes move to opposite sides outside the nucleus, and rays, like those of a star, form around them. These are called astral rays. The astray rays, together with the centrioles, which are structures within the centrosomes, form structures called asters. The chromosomes thicken and become visible under the microscope. They double along their length, except for a small, circular area of attachment at the middle. This point of attachment is known as the centromere. The four parts of the synapsed, or joined, double chromosome (also known as a tetrad) are called chromatids, as illustrated in figure two.



Chromosome Replication

Figure 2

As prophase continues, fibers develop between the two centrioles on opposite sides of the nucleus. These fibers bow outward in the center to form a three dimensional structure which looks like a football. This is called the spindle. In describing the spindle, we often refer to each end as a pole, and to the point midway between the poles as the equator. Late in prophase, the nuclear membrane dissolves, and the nucleolus disappears. The chromosomes move to the equator, pulled by their centromeres. Prophase is the longest and most complicated phase of mitosis.

Metaphase

Metaphase begins as the paired chromatids gather along the equator. The centromere of each pair pulls apart, resulting in the separation of the four chromatids into two identical chromosomes. The centromere of each new chromosome becomes attached to a fiber that extends to a pole. Chromosomes from each pair join to fibers leading to opposite poles.

Anaphase

Anaphase consists of the migration of the chromosomes from the equator to the poles. Immediately after division of their centromere, paired chromosomes seem to repel each other. Each of these identical, or homologous chromosomes moves along a fiber of the central spindle, those of a pair moving to an opposite pole. The centromeres lead and the chromosomes trail behind. Anaphase ends with the arrival of the chromosomes at the poles and the formation of clusters of chromosomes at the polar area.

Telophase

Telophase is the final stage of mitosis. It is characterized by the formation of two daughter nuclei, and the division of the cytoplasm to form two daughter cells. Soon after reaching the poles, the chromosomes lengthen and gradually unfurl into DNA strands, forming a network of chromatin material similar to that of the interphase nucleus. The spindle fibers disappear, and two new nuclear membranes surround the new nuclei.

At the same time, the cytoplasm divides into two separate parts of approximately the same size. Division of the cytoplasm is called cytokinesis. When the two cytoplasmic parts, each surrounding a new nucleus, have completely separated, two identical daughter cells have been formed, and mitosis is complete.

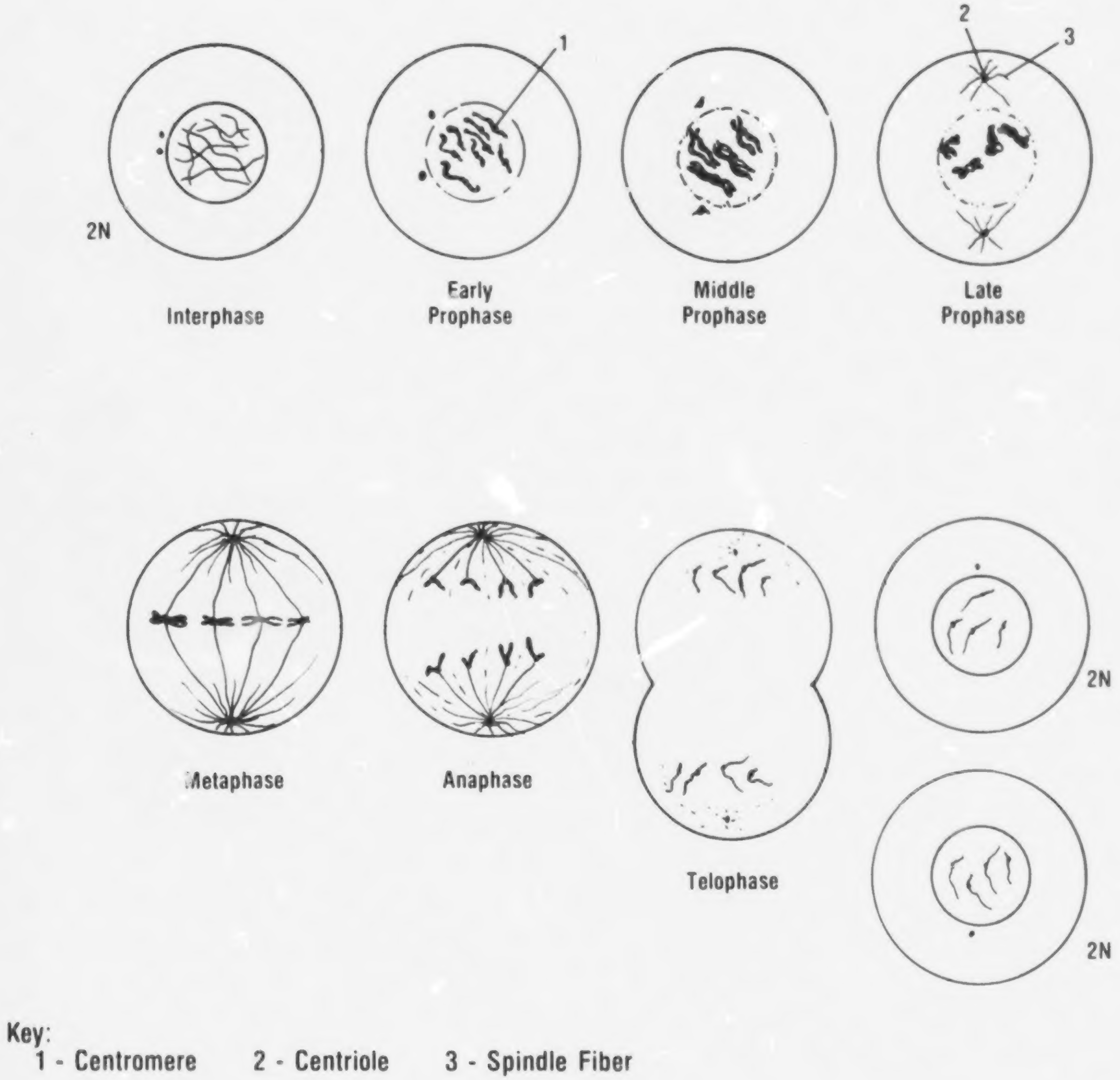
In animal cells, cytokinetic division usually begins with the appearance of a groove, or cleavage furrow, near the equator. The cleavage furrow deepens and divides the cell into two parts. It looks as if the cell is being pinched in half. The end of telophase is marked by final separation, with both new daughter cells entering an interphase stage of growth.

Mitosis in Plant Cells

Mitotic division in higher plants is basically the same as in animal cells, although some differences do exist. For example, plant cells do not have centrosomes and do not form asters in preparation for nuclear division. As a consequence, spindle fibers in dividing plant cells extend from pole to pole in a more open-ended, barrel-shaped fashion instead of in a football-like pattern.

The largest difference between animal and plant cell mitosis is in the way final division, or cytokinesis, is completed during telophase. In plant cells during telophase, a division plate begins to form from a point in the middle of the cell, and it grows from the inside toward the outside of the cell. This plate, composed of cellulose or other rigid material, eventually divides the cell into two daughter cells and becomes part of their walls. By comparison, animal cells during telophase look as if they are being pinched, or separated by an outside force.

Study the drawing of mitotic stages in an onion root tip in figure three. The root tips of onions grow very fast, and therefore many onion root tip cells are in some phase of division, thus making good specimens for mitotic studies.


2
3
1
2N
Interphase
Early Prophase
Middle Prophase
Late Prophase
Metaphase
Anaphase
Telophase
2N
2N
Key:
1 - Centromere
2 - Centriole
3 - Spindle Fiber

Mitosis

Figure 3

NOTE: Students require access to the following materials to complete this exercise: a microscope and prepared slides of mitosis in an onion root tip and in a whitefish blastula.

Onion Root Tips

Study with a microscope the phases of mitosis by examining a prepared slide of the cells of a sprouting onion root tip. First observe the cells under low power. Locate an area of the root tip where mitotic phases can best be observed, and change to the high power objective. You will probably discover that the mitotic phases are most easily seen in the region of the root between the tip of the root and where the cells begin to elongate. Study these cells closely. Locate and study a cell for each of the different mitotic phases.

1. What are these phases called? ____

____

____

2. Draw the phases as you see them in the onion root in the space provided below. Draw a cell in both early and late prophase. Label each phase, and also all identifiable cell structures.

3. What occurs during interphase? ____

____

____

____

4. What role does the spindle play in the dividing cell? ____________________________

____

____

____

5. Where does the cellulose wall form in the mother cell, and what is its function? ______

6. How can you distinguish between prophase and metaphase? ______

Whitefish Blastulae

Now observe mitotic phases in an animal cell. You will be able to observe some structures that were not present during mitosis in an onion root tip. Using a microscope, observe a prepared slide of a whitefish blastula, first under low, and then under high power.

7. In the space provided below, draw a whitefish blastula cell in each of the different phases of mitosis. Draw a cell in both early and late prophase. Label each phase, and also all identifiable cell structures. Specify structures that differ from plant cells undergoing mitosis.

Review: *complete the following*

8. Mitosis involves the replication of ____________________ and the equal division of chromatids into daughter ____________________.

9. After replication a chromosome is composed of two coiled filaments called ____________________, which are in close proximity to one another.

10. As the chromosomes become visible with a light microscope, the ____________________ membrane disappears.

11. The different phases of mitosis are ____________________, ____________________, ____________________, ____________________, and ____________________.

12. Why is the separation of chromatids important? ____________________

____

____

____

Meiosis

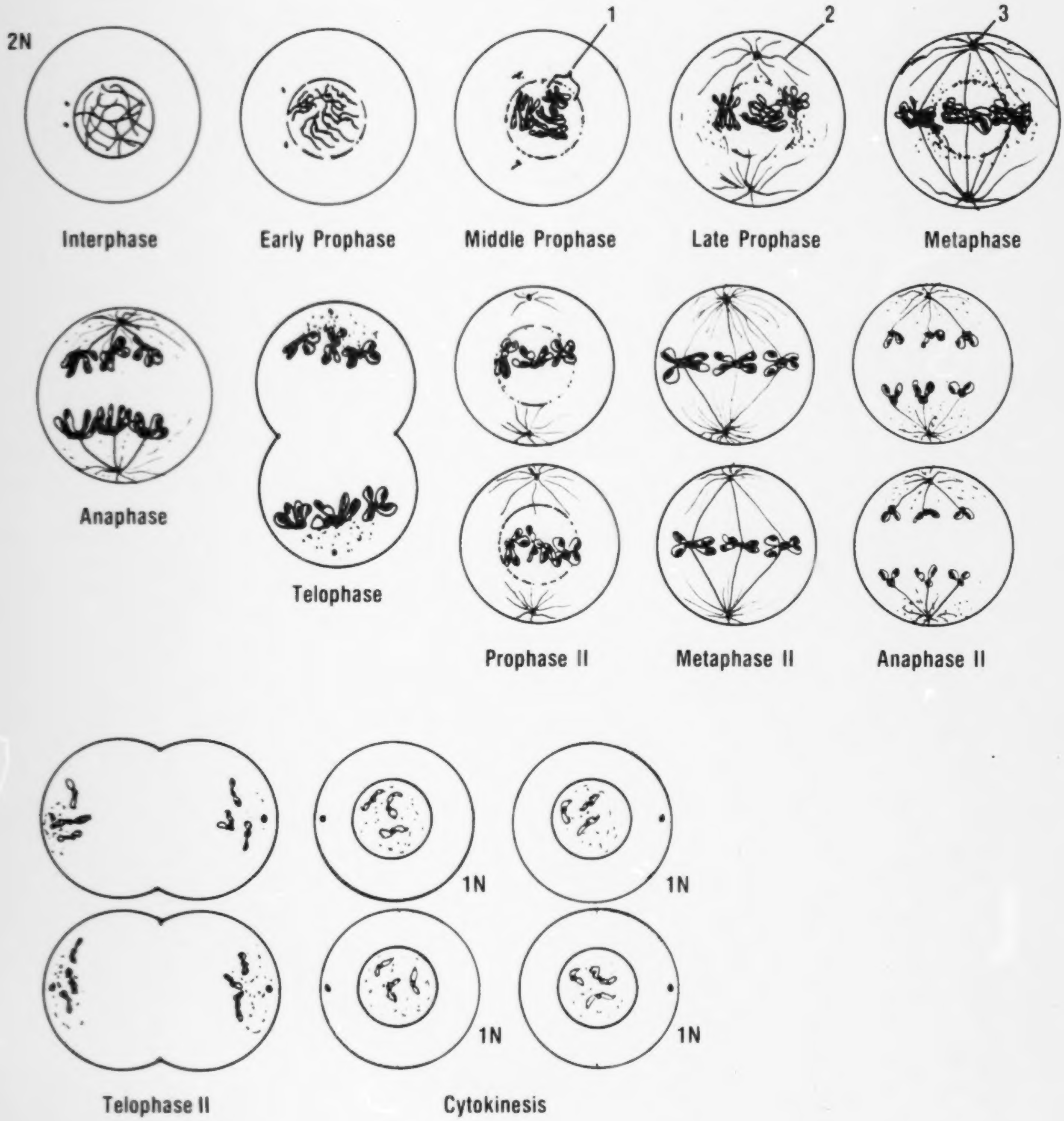
Meiosis is a cell division process which occurs only in the reproductive cells, including the reproductive cells of man. Meiosis yields cells with half the original chromosome numbers. When reproductive cells from each of two parents merge, bringing chromosome numbers back up to the total for tissues of that particular species, a unique individual with a mixed genetic endowment, half from each parent, results. See figure four on the next page for a generalized diagram of the phases of meiosis.

As you can see from the diagram, cells which undergo meiosis initially divide mitotically. The two daughter cells produced by that mitotic division then undergo further stages of division in which there is no replication of genetic material. The two daughter cells resulting from the initial mitotic division go through the following additional phases, which parallel in appearance the phases of mitosis after which they are named: interkinesis (similar to interphase, but without preparation for genetic duplication), prophase II, metaphase II, anaphase II, and telophase II.

The critical stage in meiosis appears to be interkinesis, during which time the cells prepare to divide without replicating DNA or duplicating chromosomes. Because of the interkinetic divergence from normal mitotic duplication, and the dividing of available chromosomes between daughter cells, the resulting four cells have exactly half the genetic ploidy of the original cell. The cells are defined as being haploid, or having half the number of chromosomes of the parent. With the appearance of haploid daughter cells, meiosis has been completed, and sexual reproduction is possible.

Isogametes and Heterogametes

In some organisms, the four haploid daughter cells resulting from meiosis (the four are known as gametes) fuse with others similar in size and appearance to form a new diploid organism. These similar appearing gametes are called isogametes. Reproduction in simpler organisms such as algae typically results from the merging of isogametes. In yet other organisms, such as man, the four daughter cells are dissimilar. They vary in both size and appearance according to the sex of the organism which produced them. These disparate forms are called heterogametes.


2N
1
2
3
Interphase
Early Prophase
Middle Prophase
Late Prophase
Metaphase
Anaphase
Telophase
Prophase II
Metaphase II
Anaphase II
1N
1N
1N
1N
Telophase II
Cytokinesis

Key:
1 - Tetrad 2 - Spindle Fiber 3 - Centriole

Meiosis

Figure 4

Spermatogenesis

The process of forming heterogametes in the human male is called spermatogenesis, and the resulting four cells are given the special name spermatids. Spermatids are quiescent until they grow flagellar "tails" to propel themselves through liquid. They are then called spermatozoa, or sperm cells, and in man they may live on stored cytoplasmic energy for from twelve to twenty-four hours. During this brief period they might succeed in swimming to and fertilizing an egg. If the fertilized egg fully develops, the result is a genetically unique, diploid individual.

Oogenesis

In a human female, the process of meiosis is called oogenesis, and because cellular division is unequal, only one haploid egg results. Nuclear material appears to be evenly divided between the four daughter cells, but during both anaphases I and II and telophases I and II, cytoplasmic division is unequal. The bulk of the cytoplasmic material stays with one large cell, the egg (known as an ootid in its early stages), with the three much smaller cells known as polar bodies. Polar bodies disappear rapidly, apparently being reabsorbed. The egg may live an independent, unfertilized life for perhaps two days before its cytoplasmic energy is exhausted.

Reproduction Puzzle Review

13. Review the terms and concepts you have learned in this exercise, as well as in exercise thirteen, by finding key words in the puzzle, figure five below. The words are written either vertically or horizontally. Circle the words. If you have trouble finding all the words, question fourteen will help you plug the gaps.

Mitosis/Meiosis Puzzle

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20	C	Y	T	O	S	I	N	E	S	Y	N	A	P	S	IS	S	G	M	H
21	H	A	I	N	R	T	R	N	O	T	E	T	R	A	D	M	A	U	E
22	R	U	S	P	E	R	M	A	T	O	G	E	N	E	S	I	S	T	L
23	O	D	N	A	P	L	E	N	H	V	O	N	A	S	T	E	R	A	I
24	M	H	A	P	L	O	I	D	Y	A	N	A	P	H	A	S	E	T	X
25	O	O	D	R	I	D	O	M	M	I	T	O	S	I	S	I	I	I	T
26	S	M	E	O	C	I	S	P	I	N	D	L	E	R	A	Y	S	O	T
27	O	O	N	P	A	P	I	I	N	T	E	R	P	H	A	S	E	N	E
28	M	L	I	H	T	L	S	G	E	N	E	S	H	A	L	U	C	F	L
29	E	O	N	A	I	O	I	A	P	O	L	A	R	B	O	D	Y	U	O
30	N	G	E	S	O	I	O	M	W	A	T	S	O	N	G	E	N	R	P
31	S	U	N	E	N	D	C	E	N	T	R	O	M	E	R	E	D	R	H
32	R	E	O	P	L	M	E	T	A	P	H	A	S	E	O	W	X	O	A
33	N	R	P	U	R	I	N	E	S	P	E	R	M	A	B	L	A	W	A
34	C	E	N	T	R	O	S	O	M	E	C	E	L	L	P	L	A	T	E

Figure 5

Key:

14. Fill in the following blanks. You will find the first letter of the word that completes each sentence in the figure five puzzle, according to a row or column number given to the right of the blank.

A. The substance that makes up chromosomes is ______________________________ **2.**

B. The production of sperm is called ______________________________ **3.**

C. A specialized type of cell division that results in the formation of haploid gametes is called ______________________________ **22.**

D. A cell which contains a reduced number of chromosomes is said to be ____________________ **2.**

E. Female gametes result from ____________________ **22.**

F. The nitrogen base that complements adenine is ____________________ **9.**

G. The type of cell division that insures the exact genetic makeup of the chromosome is __________ **9.**

H. During this phase chromosomes migrate to the poles: ____________________ **10.**

I. During interphase, DNA is undergoing ____________________ **21** to produce an exact duplicate of itself.

J. A single chromosome of a homologous pair is called a ______________________________ **24.**

K. ______________________________ **23** transfers messages from DNA during protein synthesis.

L. The ______________________________ **13** consists of the astral rays and the centrosome.

M. The ______________________________ **7** extends from pole to pole and develops during prophase as the centrioles move apart.

N. ______________________________ **8** are found on the chromosomes.

O. A sex cell is known as a ______________________________ **28.**

P. During ______________________________ **6** chromosomes align at the equatorial plate.

Q. The nitrogen base that complements thymine is ______________________________ **24.**

R. The growth and maintenance stage of the cell is called ______________________________ **27.**

S. A synapsed pair of chromosomes forms a ______________________________ **10.**

T. The longest phase of mitosis is ______________________________ **24.**

U. The point of attachment for the chromatid is the ______________________________ **7.**

V. A cell that contains the normal set of chromosomes is said to be ____________________ **25.**

W. An ootid and ______________________________ **9** develop from unequal division during oogenesis.

X. The process wherein two homologous pairs of chromosomes become attracted and entwined is called ______________________________ **20.**

Y. Guanine is an example of a ______________________________ **3.**

Z. Man contains twenty-three pairs of ______________________________ **20.**

AA. One of the men who discovered the structure of the DNA molecule was ______________________________ **9.**

BB. The nitrogen base that complements guanine is ______________________________ **1.**

CC. The male gamete is called the ______________________________ **9.**

DD. The dark region of cytoplasm just outside the nucleus is the ______________________________ **1.**

EE. During mitosis a ______________________________ **11** forms in the plant, whereas in animals a ______________________________ **28** forms.

FF. The DNA molecule is sometimes called a double ______________________________ **20.**

GG. The last phase of mitosis is ______________________________ **26.**

Resources

Carolina Biological. *Cell Division – Mitosis and Cytokinesis.* Filmstrip 52-1640, or slide set 48-1133 with cassette, 1985.

Educational Images. *Mitosis.* C 3025, computer disk for the Apple series, with interactive quiz package guide and back-up disk, 1984.

Encyclopedia Britannica Films. "Mitosis," #1902, "Meiosis: Sex Cell Formation," #2021, in the *Heredity and Adaptive Change* film series.

Kenkel, Leonard A. "Teaching Mitosis with Playing Cards," *The Science Teacher,* 47(6), 1980.

Sundberg, Marshall, D. "Making the Most of Onion Root Tip Mitosis," *The American Biology Teacher,* 43(7), 1981.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

anaphase
egg
heterogamete
interkinesis
interphase
isogamete
metaphase
oogenesis
ootid
prophase
sperm
spermatid
spermatogenesis
telophase

Review
14. Phases of Mitosis and Meiosis

Name________________________________

Date_________________________________

Multiple choice based on the following diagram of cell division

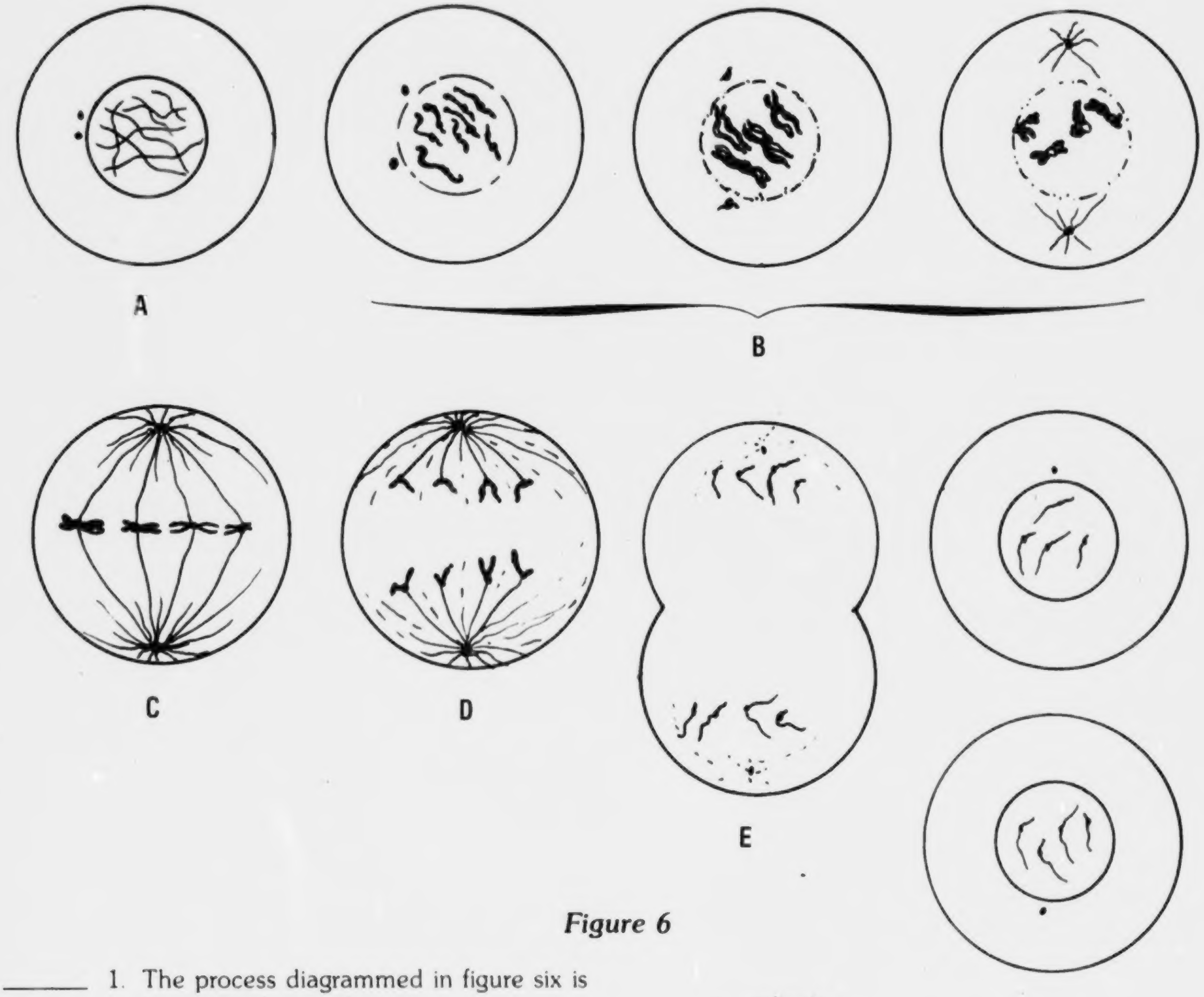


Figure 6

______ 1. The process diagrammed in figure six is
   a. spermatogenesis   c. mitosis
   b. oogenesis   d. meiosis

______ 2. The cell in figure six diagram is a(n)
   a. animal cell   c. not enough information to tell
   b. plant cell   d. both plant and animal diagram

______ 3. Letter B in the figure six diagram represents
   a. anaphase   c. interphase
   b. metaphase   d. prophase

______ 4. Letter E in the figure six diagram represents
   a. anaphase   c. telephase
   b. metaphase   d. prophase

_______ 5. Most of a cell's life is spent in the phase of
a. anaphase
b. metaphase
c. interphase
d. prophase

_______ 6. In all cells, except sex cells, the number of chromosomes is kept constant by
a. spermatogenesis
b. oogenesis
c. mitosis
d. meiosis

_______ 7. The number of sperm produced from a single primary cell is
a. millions
b. one
c. twenty-three
d. four

_______ 8. The number of eggs produced from a single primary cell is
a. millions
b. one
c. twenty-three
d. four

_______ 9. These sex cells look alike.
a. male and female
b. heterogametes
c. sperm and egg
d. isogametes

_______ 10. The purpose of mitosis is to
a. maintain the genetic unit of the cell
b. maintain the characteristics of the cell in all offspring
c. distribute genetic material identically to daughter cells
d. all of the above

_______ 11. The nuclear membrane and nucleoli disappear during
a. anaphase
b. metaphase
c. interphase
d. prophase

_______ 12. Asters develop fibers which extend from
a. opposite sides of the nucleus
b. nucleus to the nuclear membrane
c. centrosome to the edge of the cell
d. centrosome to the centromere

_______ 13. When a cell is not undergoing division, it is said to be in
a. anaphase
b. metaphase
c. interphase
d. prophase

_______ 14. The nuclear membrane reappears during
a. anaphase
b. metaphase
c. telophase
d. prophase

_______ 15. Plant cells do not contain
a. chromosomes
b. chromatids
c. centromeres
d. centrosomes

_______ 16. Plant cells cannot form
a. asters
b. spindles
c. fibers
d. poles

_______ 17. The part of the cell generally associated with the transmission of hereditary information is the
a. mitochondria
b. ribosome
c. chromosome
d. centriole

_______ 18. The formation of eggs is called
a. meiosis
b. oogenesis
c. spermatogenesis
d. mitosis

_______ 19. A cleavage furrow is found in
a. plant cells
b. animal cells
c. all daughter nuclei
d. all primary nuclei

_______ 20. The final stage of mitosis is
a. anaphase
b. metaphase
c. telophase
d. prophase

15. Exercise

Gene Mutations

When you have completed this exercise you should be able to:

1. Explain how DNA directs the synthesis of proteins.
2. Describe the chemical changes which occur in gene mutations.
3. Diagram the replication of genetic information from a section of DNA.
4. Discuss the relationship between gene mutations and disease.

Proteins

You studied the basic structure of proteins in exercise four. Now you will learn about the different groups of proteins which have been discovered, among them being the nucleoproteins, of which DNA is representative. In this process you will learn how DNA molecules are related to all other protein molecules, how a mutation can occur, and how information is passed from DNA to the cell.

Functional Roles of Proteins

Proteins perform many essential functions. Some of these are dynamic, such as transporting energy compounds, maintaining metabolic controls, and performing chemical transformations within the cell. Some proteins function structurally, or as static parts of the body, such as when protein provides the matrix for bone and connective tissue, as well as for the organism's overall shape.

Dynamic Functions of Proteins

One important group of dynamically active proteins are the enzymes. Enzymes act to catalyze chemical reactions. Almost all the thousands of different chemical reactions that occur in living organisms require a specific enzyme catalyst in order to occur at a rate compatible with life. You studied one such enzymatic reaction in laboratory seven. Production of enzymes, like all cellular chemicals, is controlled by genetic information coded on the chromosomes.

Another important group of dynamic proteins are those that transport materials within the body. For example, hemoglobin transports oxygen in the blood, transferrin carries iron in the blood, and myoglobin transports oxygen in muscles. Many drugs and toxic compounds are transported bound to proteins.

Proteins perform many specialized functions. Some, such as the immunoglobulins and interferon which combat bacterial or viral infection, function in a protective role. Fibrin is a blood protein that forms clots to stop the loss of blood from a cut. Muscle contraction is dependent upon the proteins myosin and actin. Also, many hormones are proteins. The roles of proteins are so essential to life that you will study several of them later in this manual.

One of the most important protein functions is in the control of gene activity. These gene related proteins include not only DNA and RNA, but also the proteins called histones, repressor proteins, and the proteins that form a part of ribosomes. The histones provide the protein cores around which DNA clump during mitosis and meiosis, and the repressor proteins control gene expression.

Amino Acids

There is one amazing similarity among all living things. Initially every protein of every species is synthesized as a polymer from only twenty acids known as the common amino acids. You studied the structure of some of these amino acids in exercise four. Polymers, as you should recall, are compounds which have a basic structure that is repeated like links in a chain to form a very large molecule. Protein polymers consist of at least three amino acids linked together by dehydration synthesis.

Codons

Initial synthesis of the twenty common amino acids is controlled by specific codons contained in the DNA genetic code. A codon is any group of three nucleotide bases. As discussed in exercise thirteen, the nucleotide bases on DNA are adenine (A), cytosine (C), guanine (G), and thymine (T), with uracil (U) substituting for thymine on RNA strands. Any three of these in any sequence constitute a codon. The codons occur on a DNA strand in a linear sequence of a thousand or more, and thus one DNA strand contains many codon sets and the instructions for many proteins.

Scientists have found that it is these codons, or bases in triplets, which bear the important genetic information. Sixty-four codons are possible from permutations of four bases taken by threes, as will be shown in figure one below. Each codon codes for a specific amino acid on mRNA, and the series of base triplets, or codons, on the DNA strand determines the exact order in which the mRNA directs arrangement of the amino acids into a specific protein molecule. Since there are twenty amino acids but sixty-four codons, several codons code for the same amino acid.

Also, some of these triplet combinations do not directly code amino acid formation. Some are start and end points and signal the beginning or ending of a protein chain. For example, AUG on the mRNA strand is the start signal. It also is the only codon for the amino acid methionine. In contrast to the start signal, the three stop signals, UAA, UAG, and UGA, specify no amino acid. For this reason these stop codes are sometimes called nonsense codons.

The genetic code, as expressed through mRNA, is shown in the figure one chart below. Letters on the left hand side represent the first base of a triplet, those across the top the middle base, and those on the right the final base. Uracil has been substituted for thymine since the chart describes RNA base combinations.

The Genetic Code

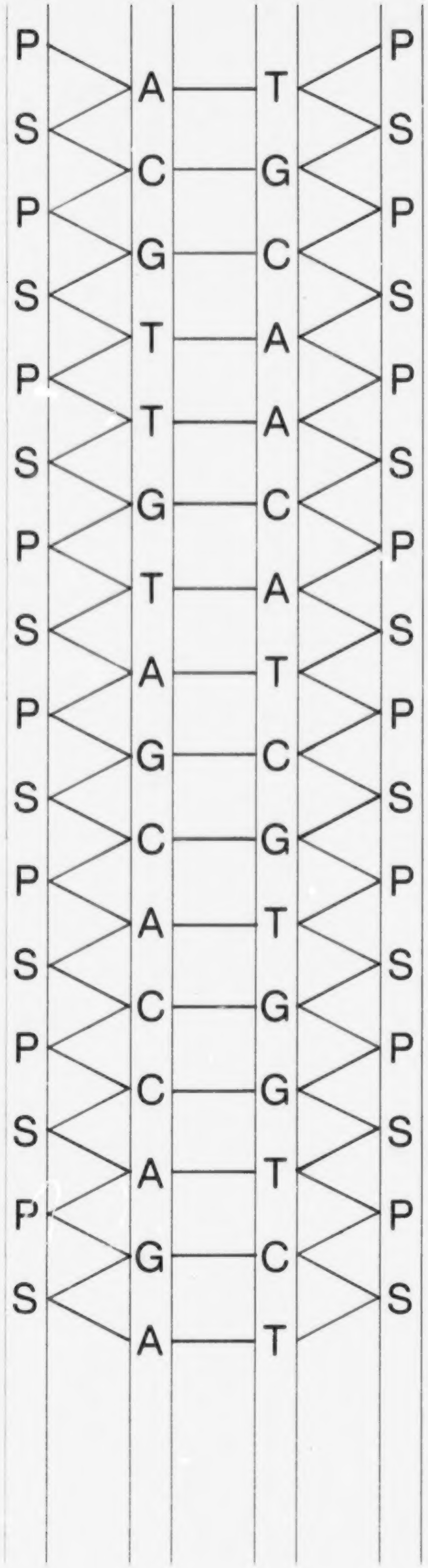
	U	C	A	G	
U	UUU Phe UUC UUA Leu UUG	UCU Ser UCC UCA UCG	UAU Tyr UAC UAA Stop UAG	UGU Cys UGC UGA Stop UGG Trp	U C A G
C	CUU Leu CUC CUA CUG	CCU Pro CCC CCA CCG	CAU His CAC CCA Gln CAG	CGU Arg CGC CGA CGG	U C A G
A	AAU Isol AUC AUA AUG Meth	ACU Thr ACC ACA ACG	AAU Asn AAC AAA Lys AAG	AGU Ser AGC AGA Arg AGG	U C A G
G	GUU Val GUC GUA GUG	GCU Ala GCC GCA GCG	GAU Asp GAC GAA Glu GAG	GGU Gly GGC GGA GGG	U C A G

Where:

Ala = alanine
Arg = arginine
Asn = asparagine
Asp = aspartic acid
Cys = cysteine
Gln = glutamine
Glu = glutamic acid
Gly = glycine
His = histidine
Isol = isoleucine
Leu = leucine
Lys = lysine
Meth = methionine
Phe = phenylalanine
Pro = proline
Ser = serine
Thr = threonine
Trp = tryptophan
Tyr = tyrosine
Val = valine

These are the twenty common amino acids, with most of them coded by more than one triplet.

Figure 1



DNA LADDER

Figure 2

Gene Mutations

The information necessary for synthesis of the unique structure of each protein, and ultimately the entire organism, is analogous to written human languages consisting of a sequence of letters which form words and sentences. If a letter is left out or changed, the entire meaning of the word, and even the sentence might change. Gene mutations operate in a similar fashion. The word mutation means a change to a gene, and some mutations have been characterized in biochemical terms, because changes in genes cause changes in the biochemistry of the cell. You will now work out some hypothetical examples of such mutations.

Assume that the diagram, figure two, represents a segment of a DNA molecule. Remember that an actual molecule is much longer, for each strand of human DNA can be millions of base pairs long. The deoxyribose sugars and phosphate groups are represented by "S" and "P," with the bases represented by their respective letters.

1. Assume that the strand on the left is the one from which a mRNA strand is to be copied. Also assume that the sequence of bases in all strands is transcribed from top to bottom, then read left to right. Write the sequence of bases in an mRNA strand that would be formed from the DNA strand shown in figure two. Remember that uracil replaces thymine in RNA, and that RNA bases are complementary to the bases on DNA.

2. Reading from left to right, divide your sequence of mRNA bases into codons. Any nucleotide base not part of a codon will not be used. Using the figure one chart, and the sequence of bases determined in question one, determine the protein segment that is specified by your sequence of mRNA codons. Do this by writing the amino acids in sequence.

Effects of Chemicals or Radiation

3. Assume that through chemical exposure or radiation a geneticist deletes (destroys and removes) the top base pair of the DNA molecule shown in figure two. To discover the effect of this kind of mutation, construct the mRNA base sequence indicated by the remaining letters, starting at the new top base pair that originally consisted of the second letters.

4. Reading from left to right, divide the sequence of mRNA bases into codons. Then, using the figure one chart and the sequence of bases determined in question three, determine the protein segment that is specified by your sequence of mRNA codons. Do this by writing the amino acids in sequence.

5. What has happened to the base on the far right in question one?

6. Does the deletion in the DNA molecule change the resulting protein? If it does, in what way?

7. Assume that by radiation the top three base pairs on the DNA molecule in figure two were deleted. Would this kind of deletion have more or less effect on the resulting protein than the deletion of a single base pair? Explain.

Replication Errors

One of the fundamental requirements for a depository of genetic information is stability. DNA provides that stability through its bases, their sequencing, and the fact that only a single complement will link with a given base. However, DNA bases are not totally exempt from processing errors during replication and strand recombination, leading to occasional incorporation of one or more erroneous bases in a new strand.

Carcinogens

Sometimes a processing error is triggered by chemicals or radiation, and sometimes the error occurs spontaneously, from an unknown cause. Carcinogens, or cancer causing compounds, act as inducers of the initial deviant cancer cells. Tobacco smoke and various industrial chemicals, for example, are known to contain particular carcinogens. Sometimes naturally occurring processing errors manifest themselves only when they are made to interact with an irritant in the environment.

Diseases of DNA repair and a susceptibility to specific cancers are inherited, but they do not always express themselves in a particular individual. For example, *Xeroderma pigmentosum* is a disorder which produces sensitivity to sunlight. Continued exposure to the sun creates, in an individual with the potentiality for the disorder, severe skin reactions ranging initially from excessive flecking and skin ulceration to the eventual development of skin cancers. Theoretically, if such an individual had been exposed to the sun in only moderate amounts, the disorder would not manifest itself, and certainly the final cancerous form would not develop.

In almost every instance of deviation, it is believed, several cycles of DNA replication are required before a permanent modification to the structure of a base leads to an irreversible change in the organism. It is thought that all organisms contain some self-correcting mechanisms which weed out most mutations. For example, researchers now write that most cancerous cells are eliminated by the human immune system before they develop into a disease. Also, defective fetuses resulting from defective sex cells usually abort spontaneously. A DNA strand must use the initially incorrect nucleotide(s) as a template for the synthesis of a complementary strand. If the deviant strand survives and duplicates through several generations, the initial change becomes permanent and the change continues into perpetuity.

Human Genetic Diseases

Genetic mutations can be passed on to offspring if the organism can live until reproductive age. Many genetically inherited diseases are caused by mutated DNA base pairs. In humans, for example, Huntington's disease (progressive degeneration of the nervous system), cystic fibrosis (glandular disorders leading to early death), thalassemia (a blood disorder primarily affecting persons of Mediterranean ancestry), Tay-Sachs disease (fatal brain defect affecting primarily those of East European Jewish ancestry), and sickle cell anemia (a blood disorder primarily affecting blacks) are a few of many possible examples of human diseases passed on through the generations.

Studies of amino acid sequences in hemoglobins show that the only difference between normal hemoglobin and sickle cell hemoglobin is the substitution of one amino acid, valine, for another, glutamic acid, in a DNA strand approximately 150 amino acids long. Small as this difference may be, impact on the sufferer consists of short-lived red blood cells and reduced oxygen transport capacity, often leading to early childhood death or reduced physical capability.

8. In a substitution mutation of glutamic acid to valine, how many different base pairs might be involved (refer to figure one)?

9. Because there are four different codons for valine and two for glutamic acid, the substitution can be made by a mutation in only one base pair. What substitutions are possible?

10. Sickle cell anemia can also be caused by the mutation of two base pairs simultaneously. Which possibility is more likely, that the mutation involves changes at two base pairs simultaneously, or a change in just one base pair? Why?

Multiple Gene Disorders

Single base pair, or single amino acid errors are relatively simple examples of how inheritance can go awry. Many human disorders, however, are not inherited through a single amino acid sequencing error, or even a single gene, but through more than one. Examples include clubfoot, harelip, cleft palate, and hydrocephalus (water on the brain).

It can be said of many disorders that they "tend to run in families." This vague phrase means it is likely that an underlying genetic error predisposes individuals from particular families to a given disease, such as heart disease, diabetes, or asthma. However, isolation and determination of exactly how the DNA deviates has not yet been achieved in most such cases, although generational studies clearly indicate the influence of genetic factors. On the other hand, the interaction between genes may be influenced, or their effects modified, by environmental factors such as upbringing and diet.

Resources

Alberch, Pere. "Possible Dogs." *Natural History*, December 1986.

Bell Telephone. *The Thread of Life*, film in two parts.

CRM McGraw-Hill Films. *Chemical Carcinogenesis: The Staging Theory*. Film #106718-3.

Human Relations Media. *Heredity, Health, and Genetic Disorders*. #763-00-CSGQ, two filmstrips with cassettes.

IBIS Media. *Genetic Engineering: Prospects for the Future*. #401-00-CSGQ, three filmstrips with cassettes.

Rensberger, Boyce. "Tinkering with Life." *Science 81*, November 1985.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

carcinogen

codon

mutation

Review

15. Gene Mutations

Name______________________________

Date_______________________________

Matching

______ 1. codon

______ 2. DNA

______ 3. mutation

______ 4. sickle cell anemia

______ 5. asthma

______ 6. interferon

______ 7. hemoglobin

______ 8. enzymes

______ 9. methionine

______ 10. cigarette smoke

A. protective function

B. functions in transportation

C. single gene disorder

D. multiple gene disorder

E. triplet of amino acids

F. carcinogen

G. a change in the DNA sequence

H. signals the start of a protein chain

I. molecular basis of heredity

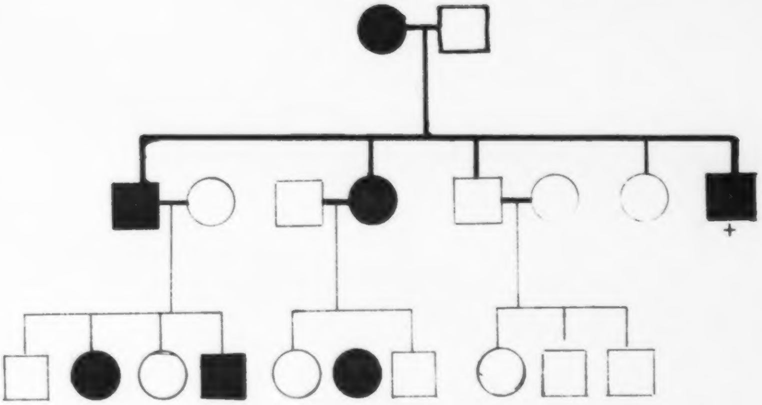
J. catalyze chemical reactions

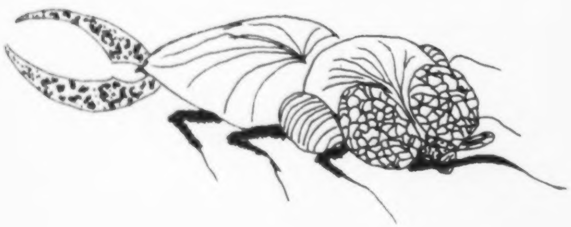
Essay

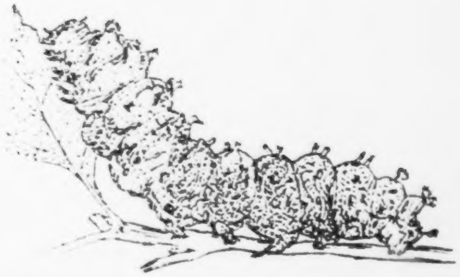
1. Discuss the primary functions of proteins in the body. ____

2. Explain how mutations can occur. ______________________________

The Flow of Life







16. Exercise

Genetics, Probability, and Punnett Squares

When you have completed this exercise you should be able to:

1. Describe the work of Gregor Mendel.
2. Understand Mendel's four laws of genetics and how they explain patterns of inheritance.
3. Construct a Punnett square of two genetic crosses which predicts the genotype and phenotype of offspring.
4. Determine whether observed traits are the same as those predicted by the Punnett square.

Gregor Mendel

The Augustinian monk, Gregor Mendel, conducted a series of experiments with garden peas which led to a new understanding of inheritance, and for which he has been hailed as the father of genetics. Although he is remembered primarily for his extraordinary studies on heredity, he was a man of wide-ranging interests.

He was born 1822 into a peasant family from the agricultural district of Heinzendorf, Czechoslovakia. Because of brilliance in school, he was allowed to continue on to high school ("gymnasium") and then university. Mendel, the poor peasant, had to work to support himself in school, which he did by tutoring others less able then himself. Unfortunately, both during high school, and later during his studies at the University of Olmütz, Mendel had to leave his studies to spend months recuperating from the effects of overwork.

On the recommendation of his physics teacher, Mendel entered the Augustinian Order of monks. With support from the Augustinian Order, Mendel was able to continue his studies without the financial worries that had plagued him during his student years. After receiving religious training, he studied agriculture and sheep breeding, as well as philosophy and natural science. He was later placed in charge of the monastery's experimental gardens where he carried out his experiments with garden peas.

When Mendel completed the theological studies required of new monks, he was assigned duties at a neighboring hospital where he ministered to the sick. Mendel became so depressed by the condition of his patients that his abbot transferred him to another district where he served as a substitute teacher. Although bright and popular with students, he never could pass the examination required for certification as a gymnasium teacher, suffering a breakdown during one attempt. He served as a substitute teacher in the Brno Technical School, while taking further courses at the University of Vienna in physics and mathematics. In 1868 he was elected abbot of the monastery, a position he held until his death in 1884.

Gregor Mendel's experiments on heredity took place over a period of nine years while he worked variously as a substitute teacher, attended the University of Vienna part time, and supervised the experimental gardens at the monastery's garden. During this period he worked out the basic principles of heredity in both plants and animals. He gave a public lecture on the topic in 1865 and published a detailed account in 1866. His paper on plant hybridization was couched in mathematical terms not appreciated by biologists of his day. It was not until the beginning of the twentieth century that the significance of his experiments and the validity of his conclusions would be honored.

Quantitative Analysis

Gregor Mendel pioneered the technique of applying a quantitative, experimental approach to the study of biology. He believed that quantitative study of complicated phenomena could yield powerful insights. Genetics was the first of the biological sciences to incorporate the quantitative method. Today most studies in the natural sciences are quantitative to some degree. As you learn more about science, you will understand that true understanding in one field of science requires knowledge and techniques from many other fields.

The biologist's dependence on physical sciences is manifold. Nothing in biology can occur in violation of physical laws, and the application of instrumental techniques and modes of thought from the physical sciences has often been of crucial importance to advances in biology. The creative biologist must be comfortable with mathematics, chemistry, physics, and still other sciences. Gregor Mendel clearly demonstrated the importance of intellectual cross fertilization by marrying mathematics to experimental botany.

Mendelian Genetics

Mendel's plant experiments were unique in several respects. Although the breeding of animals to encourage desired traits was common, no one before Mendel had quantitatively studied the inheritance of specific traits through successive generations. Mendel selected the short-lived garden pea to breed plants with identical traits. Two generations could be grown during one summer and, through several years of controlled pollination, he was able to ensure that he was working with a pure base stock. He then used these pure strains for cross-breeding to study individual traits, such as flower and seed color, seed shape, placement of flower on the stock, length of stock, etc. Mendel then used the mathematics of probability to analyze data and to formulate hypotheses which explained experimental results. He wrote formulas which explained why his pea plants looked the way they did.

Mendel was fortunate, or clever, in choosing to work with the seven characteristics he studied. All seven pea plant characteristics are located on separate chromosomes, although in Mendel's time the chromosome was unknown. Because the traits under study do not share chromosomes, his results were clear and uncomplicated by gene linkages (two characteristics residing on the same chromosome). Using only the results of his breeding experiments, Mendel provided the first clear explanation of heredity at a time when the processes of cell division, as well as heredity, were unknown.

Mendelian Laws

Mendel developed four laws of heredity to explain his experimental data. These four are called the law of dominance, the law of segregation, the law of independent assortment, and the law of random fertilization. His data demonstrated that each trait is governed by inheritance from both parents and that the trait for a characteristic may be either dominant or recessive. Traits do not "blend together" in offspring, as was commonly believed at the time, but remain separate and distinct units within the organism. If a trait does not show in a particular generation, it is recessive and may express itself in later generations. The other, of course, is the dominant trait. Two examples in humans are blond hair and blue eyes, both of which are basically recessive characteristics that require inheritance from both parents before being expressed.

The law of segregation states that during gamete (sex cell) formation Mendel's set of "unit characteristics" (a gene pair, or alleles as we call them today), which are inherited from the parents and which control a particular trait, are separated in each haploid gamete. This means that each of two gametes contains one gene from the set received from the parents.

The law of independent assortment states that a characteristic governed by a particular gene is not influenced by other genes. As an example, determination of hair color is independent of eye color. We now know that these genes must be on separate chromosomes for this law to be true. The fourth law, that of random fertilization, states that any male gamete can fertilize any female gamete of the same species.

Probability

Many new genetic concepts have been developed in the more than a century since Mendel formulated his four laws, but his work remains valid. The four laws were stated in terms of probability. By applying the mathematics of probability, you can determine how often an event should occur, as Mendel did. Correctly applied, probability predicts the average result. Sometimes outside factors alter a particular result, and the number of observed occurrences deviate from the prediction. Generally, however, if one repeats an experiment a sufficiently large number of times, the average result will approximate the mathematically predicted result. Mendel, by working with the short-lived garden pea, was able to observe a sufficient number of pea generations to gather enough data on the seven plant characteristics he had selected for study, and then to express his observed results in terms of probability.

Mendel's "Experiment 1"

"Experiment 1" in Mendel's paper was a monohybrid cross, or one involving a single characteristic. He took pollen from a true-breeding strain with wrinkled seeds and placed it on the stigmas of flowers (thereby crossing them) of a true-breeding strain with round seeds. All of the seeds of the offspring of this parental cross were round. It was as if wrinkled seeds had disappeared forever. Mendel then took the seeds of these offspring (called the first filial, or F_1 generation) and self-crossed them. The second filial, or F_2 generation offspring demonstrated a ratio of approximately three round-seed producing plants to every wrinkled-seed producing plant.

Mendel continued similar experiments with six other characteristics of peas. His experimental results are shown in the figure one chart below.

Mendel's Results from Monohybrid Crosses

Original Cross	Second Generation			
Dominant X Recessive	Dominant	Recessive	Total	Ratio
Round X Wrinkled seeds	5484	1850	7324	2.94:1
Yellow X Green Seeds	6022	2001	6023	3.01:1
Purple X White flowers	705	224	929	3.15:1
Inflated X Constricted pods	882	299	1181	2.95:1
Green X Yellow Pods	428	152	580	2.82:1
Axial X Terminal flowers	651	207	858	3.14:1
Long X Short stems	787	277	1064	2.84:1

Figure 1

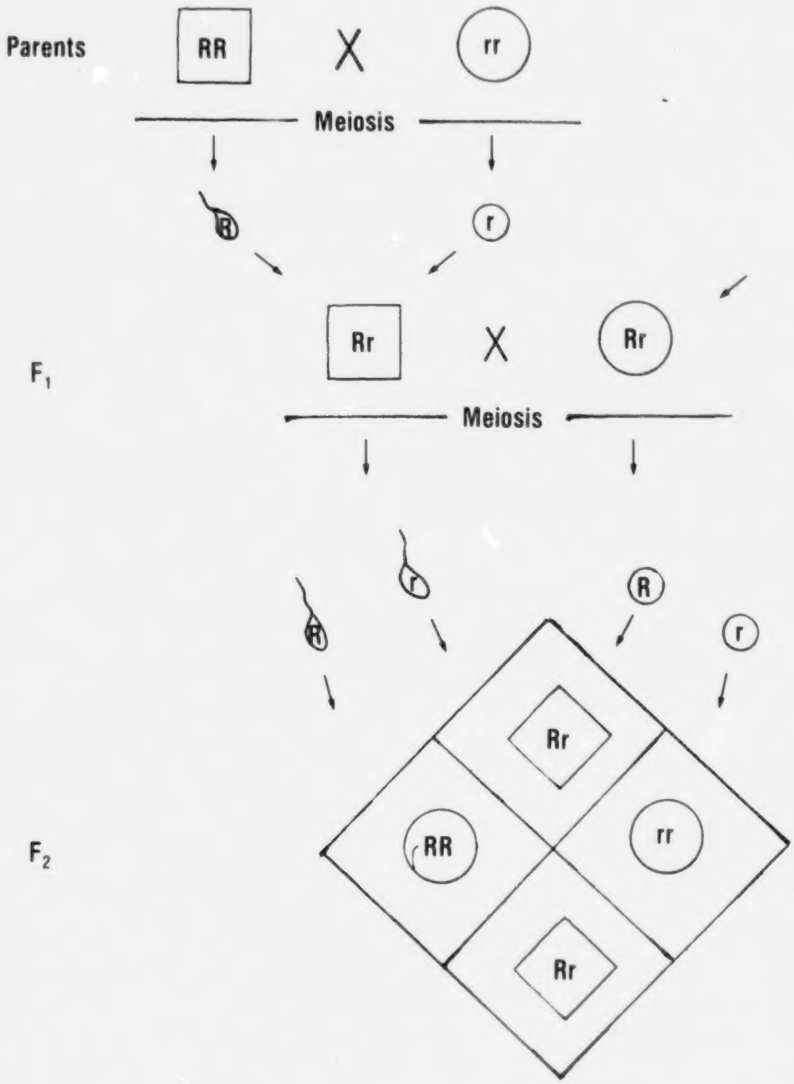
As is easily seen in the figure one chart, the ratio for each case of dominant trait compared to recessive trait is nearly three to one.

Punnett Squares

In 1905 the British geneticist R. C. Punnett devised the Punnett square as a simple way to illustrate Mendelian genetic cross results. In a Punnett square one writes down all possible gamete combinations from both the male and the female. By convention, male gamete gene possibilities are written horizontally and female gamete gene possibilities are written vertically. Horizontal and vertical lines are then drawn to form groups of cells which chart each of the diploid offspring possibilities. Reading the Punnett square is similar to reading a highway map mileage chart. An example of a simple Punnett square is illustrated in figure two of this exercise. Many people find it easier to solve genetics problems by means of an illustration of probabilities, such as that provided by a Punnett square.

True-breeding, or homozygous organisms produce gametes of only one kind. When two organisms with a different trait cross-breed, their offspring, the F_1 generation, will display the trait from the dominant homozygous parent. However, this generation also will carry the trait from the recessive homozygous parent. The offspring will **look** like the dominant homozygous parent, but they will be heterozygous, that is, they will carry the genes for both traits. Biologists say that this generation's appearance, or phenotype, is dominant, but that its actual genetic make-up, or genotype, is heterozygous for the trait.

Heterozygous organisms, such as the F_1 generation offspring in the above example, can contribute two different types of gametes to a further cross. When two heterozygous organisms cross, their offspring, the F_2 generation, show a 3:1 phenotypic ratio, or three organisms which display the dominant trait to one organism which shows the recessive trait. Genotypically, of every four F_2 offspring, one is homozygous dominant, two are heterozygous dominant, and one is homozygous recessive. This is illustrated in figure two below.



Punnett Square

Figure 2

In the following exercise, you are to construct Punnett squares of two genetic crosses to predict offspring. You will determine by coin toss whether actual results from the coin toss are the same as predicted by Punnett squares.

NOTE: Students need materials to complete this exercise. First you will need two round objects, such as coins or poker chips, and any label which will stick to them. You then will use two more round objects, green and yellow paper, scissors, and tape.

The Monohybrid cross

In a monohybrid cross only one trait is studied. Assume a monohybrid cross between two pea plants to study seed shape, as Mendel did. Further assume that both plants have a heterozygous genotype, each consisting of one allele for round seededness and one allele for wrinkle seededness. For convenience and by custom, a dominant trait is symbolized by a capital letter, and its corresponding recessive trait is symbolized by the same letter in lower case. Therefore, a heterozygous genotype for seed shape can be symbolized as "Rr," where "R" represents round seeds, and "r" represents wrinkled seeds.

1. To determine the predicted results from this cross, fill in the Punnett square, figure three below. Fill in each cell of the Punnett square by combining the genes from each parent. A many-celled Punnett square also can be used to predict the genotype for numerous offspring in multiples of four.

Rr X Rr

Gametes	**R**	**r**
R		
r		

Figure 3

2. What is the genotypic ratio of the four offspring in figure three? ______________________

3. What is the phenotypic ratio of the four offspring in figure three? ______________________

4. If the parent generation were to have twenty-four offspring instead of just four, as in the cross in figure three, how many of each genotype and phenotype would you expect?

____

____

A set of observed, or actual results representing the results of a monohybrid cross can be obtained by tossing objects, such as coins or poker chips.

5. Obtain two coins, or other round objects such as poker chips, and tape a label on one side of each. Label one male and the other female. These two round objects now represent a male and a female gamete. If you use coins, let "heads" on a coin represent "R," or round seededness, and "tails" represent "r," or wrinkle seededness. With the help of a partner, simultaneously toss both male and female labeled objects into the air. When they land, observe which side is facing up. Record the side facing you, whether it is "R" of "r," under the proper column, male or female gamete, in the chart, figure four, on the next page. Repeat this procedure for a total of twenty-four tosses.

6. Now determine the genotype of the offspring which result from each of the tosses. Record this, in combinations of capital or lower case letters, in the column labeled genotype in the figure four chart below. Also determine and record, as round or wrinkle seeded, the phenotype of each offspring in the phenotype column in the figure four chart below.

Actual Data for a Monohybrid Cross				
Trial	Male Gamete	Female Gamete	Genotype of Zygote	Phenotype of Zygote
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
24.				

Figure 4

7. Total the observed genotypes recorded in figure four which are RR, Rr, and rr. Also total the observed phenotypes which result from these genotypes, noting the totals for round seeds and wrinkled seeds. Write these totals in the figure five chart below.

TOTAL OBSERVED RESULTS Number of Offspring			
Genotype		Phenotype	
RR		Round	
Rr		Wrinkled	
rr			

Figure 5

8. How do your observed results compare with the predicted results you obtained from the Punnett square in figure three?

9. Do you think that the observed and the predicted results would be more similar if you tossed your objects a thousand times instead of just twenty-four times? Why or why not?

10. How do your observed results compare with Mendel's observed cross results as reported in "Experiment 1" and as shown in figure one?

The Dihybrid Cross

A dihybrid cross is a cross in which two traits are under study. Assume that a cross is made between two pea plants. Further assume that both plants have heterozygous genotypes for two traits, one trait consisting of an allele for yellow seeds and an allele for green seeds, and the other trait consisting of an allele for long stems and an allele for short stems.

Remember that for convenience and also by custom, a dominant trait is symbolized by a capital letter, and its corresponding recessive trait is symbolized by the same letter in lower case. Therefore, in our hypothetical dihybrid cross, a heterozygous genotype may be symbolized by "YyLl," where "Y" represents yellow seeds, "y" represents green seeds, "L" represents long stems, and "l" represents short stems.

11. To determine the predicted results from this cross, fill in the Punnett square given in figure six below. Fill in each cell of the Punnett square by writing the proper gene combinations derived from the parents. The completed Punnett square will show the distribution of predicted results.

YyLl X YyLl

Gametes	**YL**	**Yl**	**yL**	**yl**
YL				
Yl				
yL				
yl				

Figure 6

12. What is the genotypic ratio of the sixteen offspring in figure six?

____

13. What is the phenotypic ratio of the sixteen offspring in figure six?

____

14. If the parent generation were to have thirty-two offspring instead of just sixteen, as in the cross given in figure six, how many of each genotype and phenotype would you expect?

____

____

A set of observed, or actual, results representing the results of a dihybrid cross can be obtained by tossing objects, such as coins or poker chips, as you did when testing a monohybrid cross.

Obtain four identical round objects, such as coins or poker chips. Tape green paper on one side and yellow paper on the other side of two of the objects. Paper color represents seed color. Label both sides of one of the papered objects as male and the other as female. Take two other identical objects, and tape paper on both sides of these. Label one side of each object with "L" for long stems, and the other side of each as "l" for short stems. Also, label one of these two as male, the other as female.

15. With the help of a partner, simultaneously toss all four objects in the air. When they land, observe which side is facing up. Repeat this procedure for a total of thirty-two tosses. Record your results in the chart, figure seven, on the next page, using the same letters in the cells of the chart as you did when filling in the Punnett square in figure six.

16. Now determine the genotypes of the offspring which result from each of the tosses. Record this, in combinations of capital or lower case letters, in the column labeled genotype in the figure seven chart. Also determine and record the phenotype of each offspring in the phenotype column in the figure seven chart.

Actual Data for a Dihybrid Cross						
Trial	Color of Seed		Length of Stem			
	Male Gamete	Female Gamete	Male Gamete	Female Gamete	Genotype of Zygote	Phenotype of Zygote
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						
26.						
27.						
28.						
29.						
30.						
31.						
32.						

Figure 7

17. Next record the totals for observed genotypes in the left portion of the following chart, figure eight. Then record observed phenotypes in the right portion of the same chart.

TOTAL OBSERVED RESULTS Number of Offspring			
Genotype			**Phenotype**
YYLL		**Yellow seeds, Long stems**	
YYLl		**Yellow seeds, Short stems**	
YYll		**Green seeds, Long stems**	
YyLL		**Green seeds, Short stems**	
YyLl			
Yyll			
yyLL			
yyLl			
yyll			

Figure 8

18. How do your observed results compare with the predicted results you obtained from the Punnett square in figure six?

19. Do you think that the observed and predicted results would be more similar if you tossed your objects a thousand times instead of just thirty-two times? Why or why not?

20. How do your observed results compare with Mendel's results as reported in "Experiment 1" and as shown in figure one?

21. What Mendelian laws are operating if the predicted numbers of genotypes and phenotypes are similar to those obtained from results observed in your simulated dihybrid cross?

Review

22. Mendel found that certain tall pea plants produce short plants in a second generation. Which of his laws did he formulate from this observation?

23. Mendel reasoned that a pair of genes are separated in different gametes during meiosis. Which of his laws is based upon this reasoning?

24. The gene for black coat color is dominant in guinea pigs. How is homozygous black different from heterozygous black, even though the guinea pigs look alike?

25. When two hybrid animals are crossed, there appear among the offspring homozygous dominant, heterozygous dominant, and homozygous recessive individuals. Explain.

26. When two parents who are heterozygous for one trait are crossed, what ratio of offspring ought to show the dominant trait, and what proportion the recessive trait?

27. Explain the law of independent assortment.

28. Why should a hybridizer know which traits in plants or animals with which he is working are dominant or recessive?

29. Based on the law of independent assortment and the number of contrasting traits Mendel investigated, what would you believe to be the minimum number of chromosomes in a pea plant? Why?

Resources

Denoyer-Geppert. *The Path to Genetics: Mendel's Laws.* #DG5-69520, a set of 4 filmstrips with cassettes.

Duffy, Kevin. "The Legendary Ostrich People," *Science Digest*, 90(6), 1982.

Genetics Learning System. *Mendelian Inheritance*, units 1(EP 2222) and 2(EP 2223), slides and cassettes. The entire program, of which only two slide sets are listed here, was developed by the School of Medicine, University of New Mexico. There are a total of eighteen valuable programs in the entire series.

Keller, Evelyn Fox. "McClintock's Maize," *Science 81*, 2(8), 1981.

Kinnear, Judith. *Heredity Dog.* 1 diskette and back-up with teaching guide, #538-00-MSAG (Apple), or #428-00-MSCG (Commodore).

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

allele
dihybrid
filial generation
genotype
heterozygous
homozygous
Mendel, Gregor
monohybrid
phenotype
Punnett square

Review

16. Genetics, Probability, and Punnett Squares

Name______________________________

Date_______________________________

Matching

______ 1. Heredity

______ 2. Genotype

______ 3. Phenotype

______ 4. Homozygous

______ 5. Heterozygous

______ 6. Environment

______ 7. Law of segregation

______ 8. Law of dominance

______ 9. Allele

______ 10. Homozygous recessive

A. External forces that influence expression of genetic make-up

B. One trait is dominant over another

C. Actual genetic make-up of an organism

D. Rr

E. Effect of a gene on an organism

F. One of a pair of genes

G. Involves two pairs of genes on different chromosomes

H. RR

I. What an organism looks like

J. rr

Diagram the F_1 and F_2 generation when a black female guinea pig (BB) is crossed with a white male guinea pig (bb).

11 & 12. F_1

13. What is the phenotype of the offspring? ____________________

14. What is the genotype of the offspring? ____________________

15 & 16. F_2

17. What are the phenotypes of the offspring? ____________________

18. What are the genotypes of the offspring? ____________________

19. What is the genotypic ratio of the F_2 cross? ____________________

Short answer

20. Who is called the "father of genetics"? ____________________

21. Upon what mathematical concept did he base his studies of pea plants? ____________________

22. By using any one of the seven traits of garden peas, give an example of the law of independent assortment.

____

____

23. When two characteristics, or traits, are being considered in an organism, what is the cross called?

____

24. In genetics, what is meant by the predicted results? ____________________

____

25. In pea seeds, round (R) is dominant over wrinkled (r) and yellow (Y) is dominant over green (y). If two plants heterozygous for these traits are crossed, 9/16 of the offspring seeds will exhibit what phenotype?

____

17. Exercise

Monohybrid and Dihybrid Crosses

When you have completed this exercise you should be able to:

1. Solve monohybrid cross problems involving one characteristic.
2. Solve dihybrid cross problems involving two independent characteristics.
3. Predict, given the genotype of two individuals, the probability for a specific genotype or phenotype of offspring.

Monohybrid Crosses

Review exercise sixteen for a discussion of monohybrid crosses and Punnett squares, and then solve the following problems, showing all computations. Remember that any letter may represent a given trait, but that the dominant allele is shown by a capital letter, and the corresponding recessive allele by the same letter in lower case. Use Punnett squares, where applicable, to calculate your answers.

1. Cross a hybrid pea plant which bears its flowers axially with a pure pea plant which bears its flowers terminally. What genotypic and phenotypic offspring will result, and in what ratio?

2. Cross a hybrid pea plant with inflated-seed pods with a pure constricted-seed pod plant. What genotypic and phenotypic offspring will result, and in what ratio?

3. Cross a homozygous yellow-seeded pea plant with a homozygous green-seeded pea plant. Refer to figure one of exercise sixteen to determine the dominant trait. What genotypic and phenotypic offspring will result, and in what ratio?

4. Short hair is dominant over long hair in guinea pigs. Cross a pure, short-haired female guinea pig with a pure, long-haired male. If their offspring produce an F_2 generation, what genotypic and phenotypic offspring will result in that F_2 generation, and in what ratio?

5. Two brown mice were mated, and twelve offspring resulted. Nine of the offspring were brown, yet three of them were white. How can this be explained? Show all work.

6. A green parrot was trapped near downtown Anchorage and mated with a yellow parrot trapped near New Orleans. These parrots were very unusual in that they had 500 offspring, 250 green and 250 yellow baby parrots. What were the genotypes of the parent parrots?

7. During a recent hunting season a male and female otter were captured and mated. Both otters were of the southern species, so they were dark brown in color. Once the offspring were born, the owners noticed quite a few cream-colored otters running around, as well as a large number of dark brown otters. If both parents were heterozygotes and there were 48 little brown otters, how many little cream-colored otters were there?

8. For this question use your imagination. A pink elephant and a green elephant were mated and only pink baby elephants were born of the union. If two of these offspring were mated and eventually produced a total of 64 baby elephants, how many of these should be pink and how many should be green?

9. Brown color in mice is dominant over albinism. In a given cross between a brown mouse and an albino mouse, six of the offspring were brown and five were albinos. What were the genotypes of the original brown parents?

10. Starchy grain is dominant over sugary grain in corn. If, in a cross between these two types, 58 of the offspring were sugary, how many would be starchy?

11. A certain white-fruited squash, when self-fertilized, produced both white and yellow-fruited squash offspring. If 21 of the offspring were yellow, how many white squash would be expected?

12. Short hair is dominant over long hair in guinea pigs. A short-haired guinea pig, one of whose parents was a long-haired animal, was mated with a long-haired guinea pig. If, blindfolded, you selected one of their litter from the cage, what is the chance you would get a long-haired animal?

13. If an animal with the genotype Cc produces 100 eggs, how many of these eggs should have the genetic formula C? How many the formula c? How many the formula Cc? Why?

14. Applying the rules relating to the choice of symbols for genes, make a number of matings between trotting horses, Pp and Pp, and obtain 24 foals. How many of these foals would be pacers? Why?

15. If two parents which have the same visible characteristics produce some offspring which are like the parents, and some different, write the formulas of the parents using any symbols you choose.

16. In eye color, the darker colors are usually dominant over lighter ones. A brown-eyed boy whose mother had blue eyes married a brown-eyed girl whose father had blue eyes. What is the chance that their first born child will be blue-eyed? Why?

17. Two long-winged fruit flies mated and produced long-winged and vestigial-winged offspring. What were the genotypes of the parents?

18. Congential cataracts (opacity of the lens) in human beings is dominant over normal eyesight (no cataracts) It may sometimes be cured by an operation. A normal woman married a man homozygous for the gene for cataracts. They had two children, A and B. The man then had an operation, and the cataracts were successfully removed. They then had two additional children, C and D. What would be the phenotypes of children A, B, C, and D. Explain.

19. Given the uncertainty as to whether an individual is Cc or CC, would it be easier to resolve the uncertainty in humans or rabbits? Why?

____

____

20. In cattle, hornless is dominant over horned cattle. A certain bull was mated with four cows:

Cow #1 was hornless and had a horned calf
Cow #2 was horned and had a horned calf
Cow #3 was horned and had a hornless calf
Cow #4 was hornless and had a hornless calf and a horned calf

What was the phenotype and genotype of the bull?

Dihybrid Cross Problems

Review exercise sixteen for a discussion of dihybrid crosses, and then solve the following problems, showing all computations. Remember that any letter may be used for a given trait, but that the dominant allele is represented by an upper case letter, and the corresponding recessive allele by the same letter in lower case. Use Punnett squares to calculate your answers where applicable.

21. If a female (RRyy) is crossed with a male (rrYY)

a. What is the phenotype of their offspring? ____________________

b. What is the genotype of their offspring? ____________________

22. Cross the offspring resulting from question #21 and draw the results in a Punnett square in the space provided below. Also answer the following questions.

a. What are the kinds of gametes formed? ____________________

b. What are the different kinds of phenotypes? ____________________

c. What is the ratio of phenotypes? ____________________

d. How many different kinds of genotypes are there? ____________________

23. Cross a female (AAii) with a male (AaIi) in the space provided below.

a. What are the kinds of gametes formed? ________________________________

b. What are the different kinds of phenotypes? ________________________________

c. What is the ratio of phenotypes? ________________________________

d. How many different kinds of genotypes are there? ________________________________

24. Cross a female (ttcc) with a male (TtCc) in the space provided below.

a. What are the kinds of gametes formed? ________________________________

b. What are the different kinds of phenotypes? ________________________________

c. What is the ratio of phenotypes? ________________________________

d. How many different kinds of genotypes are there? ________________________________

25. Cross a female (ggii) with a male (ggIi) in the space provided below.

a. What are the kinds of gametes formed? ________________________________

b. What are the different kinds of phenotypes? ________________________________

c. What is the ratio of phenotypes? ________________________________

d. How many different kinds of genotypes are there? ________________________________

26. In corn, starchy grain is dominant over sugary grain, and purple endosperm is dominant over white endosperm. A pure starchy grain, purple endosperm plant is crossed with a pure sugary grain, white endosperm plant and only starchy grain, purple endosperm plants result. If these plants of the F_1 generation are self-crossed, what genotypes and phenotypes are to be expected? Show your work in the space provided below.

27. In human beings, dark hair is dominant over light hair, and brown eyes dominant over blue eyes. A dark-haired brown-eyed man married a light-haired, blue-eyed woman and all their children had brown eyes and dark hair. One of these children married an individual heterozygous for both dark hair and brown eyes. What phenotypes and genotypes would be possible among the offspring of this marriage?

28. In honey bees, black body color (B) is dominant over yellow body color (b). Short bodies (S) are dominant over long bodies (s). Cross a homozygous black, long-bodied bee with one that is homozygous recessive for both traits. Show the results in a Punnett square.

29. In Martians, square heads (S) are dominant over round heads (s), and green eyes (G) are dominant over purple eyes (g). What will be the phenotypes of the offspring of a cross between two heterozygous square-headed, green-eyed Martians?

30. In reindeer, black noses are dominant over red, and walking is dominant over flying. What are all the possible genotypes and phenotypes of Rudolph's parents? Also, give the possible genotypes and phenotypes of his siblings. Hint: it helps if you remember the story.

31. In tomatoes, red fruit is dominant over yellow, and round fruit is dominant over oval. What would be the genotypes of the parents in the following crosses?

    a. A red-fruited plant is crossed with a yellow-fruited one, and it bears offspring, half of which bear red fruit, half yellow.

    b. Two red-fruited, round-shaped parents produce many offspring which look just like them. However, a few offspring are red-fruited but oval-shaped, and a few are yellow-fruited but round-shaped. One offspring is even yellow-fruited and oval-shaped, and everyone is wondering where it came from!

32. In humans, right handedness (R) is dominant over left handedness (r), and brown eyes (B) are normally dominant over blue eyes (b). These genes are on different chromosomes. A right-handed, blue-eyed man married a right-handed, brown-eyed woman. They have two children, one of whom is left-handed and brown-eyed, and the other right-handed and blue-eyed. By a later marriage with another woman, who is right-handed and brown-eyed, this man became the father of nine more children. All nine children were right-handed and brown-eyed. Use the space provided below to work out the answers to the following questions.

a. What is the most probable genotype of the man? ____________________

b. What is the most probable genotype of the first wife? ____________________

c. What is the most probable genotype of the second wife? ____________________

33. In certain chickens, silky feather is caused by an allele recessive to that for normal feathers. Also, white plumage is dominant over colored. In a certain population of Leghorns (a white chicken), it was found that while most offspring looked like typical Leghorn chickens, a few had silky, white feathers, while a few others had normal-textured, but colored feathers. Also, every once in a great while there existed a chicken with silky, colored feathers. This is most un-Leghorn-like. Please explain to the farmer what has happened in his flock.

34. In man, cataracts and excessive bone fragility seem to depend on separate dominant genes. A man with cataracts but normal bones married a women with fragile bones but normal eyes. The woman's father had normal bones. Compute the probabilities that their first child will have.

a. No abnormalities ____________________

b. Cataracts but normal bones ____________________

c. Normal eyes but fragile bones ____________________

d. Both abnormalities ____________________

e. At least one of the two abnormalities ____________________

Just so that you know that you can work hybridization problems of any number of crosses, work the following problem, which is a trihybrid cross problem.

35. In guinea pigs, black coat color is due to a dominant gene (B) and white to a recessive allele (b), short hair is due to a dominant gene (S) and long hair to a recessive allele (s), and rough coat (R) is dominant over that for a smooth coat (r). Cross a homozygous rough, short-haired, black guinea pig with a smooth, long-haired, white one. What are the phenotypes of the F_1 and F_2 generations? Show your work in a Punnett square in the space provided below.

Review

17. Monohybrid and Dihybrid Crosses

Name____________________________________

Date_____________________________________

Solve the following problems (working space is provided below each problem).

1. Two guinea pigs were crossed and twelve guinea pigs were born. Nine of them were brown and three of them were white. What are the genotypes and phenotypes of the parents?

____

____

2. A brown otter and a white otter (very rare) were mated, and, as seldom happens, one hundred offspring were obtained. There were 51 white and 49 brown baby otters in this litter. What were the genotypes of the parents?

____

3. Two homozygous mice were crossed and all of one type resulted. Two of these offspring were crossed and five baby mice resulted, some black and some white. What was the genotype of the F_1 generation?

____

4. Two green, heterozygous plants were crossed and sixteen yellow offspring resulted. How many green plants also resulted from this cross?

____

5. A gray mouse and a tan mouse were crossed and ten tan mice resulted. Some gray mice were also born. How many? ______

6. Two heterozygous, very unusual elephants were mated and seventy-two little elephants resulted. Assuming that orange is dominant over pink in these unusual, prolific elephants, how many babies were orange and how many were pink?

______

7. A brown-eyed woman whose father had blue eyes married a man with blue eyes. What is the chance that their first child will be born with blue eyes?

______

8. Two gray wombats were crossed, and 48 little gray wombats were born, as well as some white ones. How many white wombats resulted from this mating?

______

9. A black, long-haired rabbit was mated with a white, short-haired rabbit, and only black, long-haired rabbits resulted. Two of these offspring were then mated. What are the chances of getting a black, short-haired rabbit in the F_2 generation?

10. In a certain species of plant, tall stems aré not dominant over short ones, but wrinkled seeds are dominant over round seeds. A tall-stemmed, wrinkled-seeded plant was crossed with a short-stemmed, round-seeded plant. Show the results of this cross in a Punnett square.

18. Exercise
Incomplete Dominance, Sex-Linked Inheritance, and Nondisjunction

When you have completed this exercise you should be able to:

1. Solve genetic problems involving incomplete dominance in alleles.
2. Solve genetic problems involving sex-linked inheritance.
3. Explain what happens in chromosomal nondisjunction.

Incomplete Dominance

Incomplete dominance is present when neither allele of a pair is dominant over the other, and heterozygous offspring show a blending of the two traits. However, the alleles themselves have not "blended," because the original traits, plus the apparently blended traits, show themselves phenotypically in the F_2 generation. Actually, cases of incomplete dominance are more common than those of complete dominance. In hindsight, it was fortunate for Mendel's work that he considered only cases of complete dominance.

The crossing of some flowers shows how incomplete dominance works. For example, if a true-breeding, red-flowered snapdragon is crossed with a true-breeding, white-flowered snapdragon, the F_1 generation will be pink-flowered. Pink is a mixture intermediate between red and white. This result is still explainable in terms of Mendelian genetics. If the F_1 generation is then self-crossed, the resulting F_2 generation shows a distribution ratio of one red:two pink:one white. Clearly the genes have shown that they maintain their original form. The only change to Mendelian genetics which explains incomplete dominance is to recognize heterozygotes which show a phenotype intermediate between those of two homozygotes.

When working problems of incomplete dominance, all letters used to denote incompletely dominant traits are given in lower case, with a different letter representing each allele. The heterozygous condition, then, is denoted by two different lower case letters.

Work the following problems on incomplete dominance.

1. The form of hair found in caucasians of European descent illustrates incomplete dominance. Straight hair (s) is incompletely dominant over curly hair (c), with the intermediate, or heterozygous, condition being wavy hair (sc). A wavy haired person and a straight haired person marry and have two children. Space is provided below for you to work this problem, using a Punnett square as needed.

   a. What is the chance, stated as a ratio, that the first child will be straight haired? ____________________

   b. What are the chances that the first two children will be straight haired? ____________________

2. In snapdragons, tall is dominant over dwarf, and red flowers are incompletely dominant over white, the heterozygote being pink. A pure tall, white-flowered plant is crossed to a pure dwarf, red-flowered plant, and the F_1 generation is then self-fertilized. Give the genotypic and phenotypic results of the F_2 generation, using a Punnett square in the space provided below.

3. In cats, tiger pattern is dominant over black color. Genes for tail length are on a separate chromosome. One allele for tail length produces cats with no tail at all. Another allele for tail length produces cats with long tails. The heterozygous condition produces a cat with a bobbed tail. If two heterozygous tiger-patterned cats, one with a long tail and one with a bobbed tail, mate, what percentage of their offspring will have the following traits?

   a. What fraction of the offspring will be black in color? ____________________

   b. What fraction of the offspring will have no tail? ____________________

   c. What fraction of the offspring will be both black in color and bobbed-tailed? ____________________

4. A farmer notices that a black hen has mated with a white rooster, and that all the offspring are an unusual shade of feathers called Andalusian blue. He wishes to establish a true breeding flock of Andalusian blue chickens, and, as a first step, he mates the Andalusian blues. The offspring from this cross are three black chicks, five white chicks, and nine blue chicks. Explain the genetic basis of blue color and advise the farmer in his efforts to establish this flock. Space is provided below to work this problem.

   ____

   ____

   ____

   ____

   ____

5. In question #4, what offspring would you expect from mating a blue chicken with a white one? A blue one and a black one? ______________________________

____

Sex Determination

Sex is determined differently in different organisms. The sex of a honey bee, for example, depends on whether it developed from a fertilized or unfertilized egg. A fertilized egg is diploid, and it gives rise to a female bee, which can develop into either a worker or a queen, depending upon its diet during larval life. An unfertilized egg is haploid and gives rise only to a male drone.

In humans, the twenty-third chromosome pair determine the sex of the individual. The other twenty-two pairs of chromosomes are called autosomes. Two X chromosomes produce a female, and one X and one Y chromosome produce a male. In humans the man's sperm determines the sex of a baby, because a woman contributes only X chromosomes. This particular sex determinant is not true for some other organisms. For example, in birds and butterflies, males are XX and females are XY. In these organisms, the female produces two types of gametes. Thus, the sex of the offspring is determined by the egg, not by the sperm, as in the case of humans.

Sex-linked Inheritance

In both *Drosophila,* or fruit flies, and in humans, the Y chromosome is almost devoid of genetic content, other than that which determines maleness, whereas a substantial number of genes are carried on the X chromosome. (Fruit flies have been used extensively to study sex-linked inheritance, because the chromosomes in their saliva are easily seen, they reproduce rapidly, and they exhibit sex linkages similar to humans). More than one hundred genes have been detected on the human X chromosome. They affect a wide variety of characteristics, many of which have nothing to do with sexual differentiation. Since the inheritance of these genes corresponds to the inheritance of the X chromosome, they are said to be X-linked.

X-linkage was discovered when Thomas Hunt Morgan, who worked extensively with fruit flies, discovered that some traits which should have been expressed in a 3:1 ratio were not. For example, fruit fly eye color is a sex-linked trait carried on the X chromosome, not the Y. Normal fruit fly eye color is red, the recessive eye color white. When a normal-eyed female fruit fly who is heterozygous for eye color is mated with a normal-eyed male, the following offspring result.

Where X^RX^r represents the female, and X^RY represents the male

	X^R	Y
X^R	X^RX^R	X^RY
X^r	X^RX^r	X^ry

All females are red-eyed;
one-half of all males are red-eyed, and one-half of all males are white-eyed.

Note that traits linked to the sex chromosomes are denoted as superscripts to the X and Y chromosome. Also note that heterozygous females are carriers of the trait without exhibiting the symptoms of the white-eyed disorder. Males lack a second X chromosome which would mask the effects of the disorder.

Work the following problems on sex-linked inheritance, using Punnett squares as necessary.

6. A red colorblind man married a women who was homozygous normal for color vision, and they had two children, one boy and one girl. What are the chances, stated as a ratio, that these children will be colorblind? ____________________________________. Space is provided below to work this problem. Red colorblindness is denoted as a superscript r on the X chromosome, while normal vision is X^R.

7. A normal man whose father was red colorblind married a red colorblind woman. What are the chances of the first child being red colorblind?

____

8. A woman whose father was green colorblind married a man normal for color vision. What is the chance that their first born child will be colorblind? ____________________________________. Green colorblindness is denoted as a superscript g on the X chromosome, while normal vision is X^G.

9. A man whose mother was green colorblind married a woman whose mother was also colorblind. One-half of their offspring can be expected to be colorblind. What are the genotypes of the parents?

____

____

10. A man with normal color vision married a woman who is normal for color vision but who thinks that one of her parents may have been colorblind. They had two children, a boy and a girl, and one of them is colorblind. Which one is colorblind, and why?

11. Sometimes an individual can have both red and green colorblindness. This would be shown as $X^{rg}Y$. A red-green colorblind man married a normal woman whose father was colorblind. They have eight children, four boys and four girls. Assuming an equal distribution of color blindness and normal color vision among the children, how many of each sex would be expected to be colorblind?

Hemophilia is another example of a sex-linked trait. The allele for normal blood clotting is dominant, and it is represented by the superscript H on the X chromosome. The recessive gene represents blood which cannot produce antihemophilic globulin (Factor VII) that clots blood. It is represented by the lower case superscript h on the X chromosome.

12. A woman with no record of hemophilia in her ancestry married a normal man whose father was a hemophiliac. How many bleeders would be expected in this family if the parents had two boys and two girls?

13. A woman heterozygous for hemophilia married a man who was normal. What are the chances that any of her children will have hemophilia?

14. A normal man whose father was a hemophiliac married a normal woman. What are the chances their first born child will have hemophilia?

15. A woman whose father was a hemophiliac married a man who was a hemophiliac. What are the chances of the third male child being a hemophiliac?

16. Mrs. Houghton is unsure whether she carries the gene for hemophilia. She does know that her grandmother on her father's side had hemophilia and that her own mother was normal. Can you help Mrs. Houghton determine her genotype? What is it?

17. Mr. and Mrs. Mifflin had four children, Irving, Julius, Mona, and Fern. Here is some basic information about the children:

Mona — homozygous normal for hemophilia
Irving — normal for hemophilia
Julius — has hemophilia
Fern — heterozygous for hemophilia

What are the genotypes and phenotypes of the parents?

18. Mr. and Mrs. Krajzenski had eight children over the span of their marriage. As chance would have it, four were girls and four were boys. One-half of the boys were hemophiliacs and the others were normal. One-half of the girls also had hemophilia. The other two daughters did not show the disorder. What are the genotypes and phenotypes of the parents?

19. Mrs. Lowell, whose father had hemophilia, and whose mother was normal, was married to Mr. Lowell (naturally), whose father was normal and whose mother had hemophilia. Mr. and Mrs. Lowell are expecting their first child. If this child is a girl, what are the chances of the girl having the gene for hemophilia?

Nondisjunction

Sometimes a mutation occurs in a cell which partially or completely alters one of the chromosomal pairs which carry the genetic traits for the organism. When a mutation occurs during meiosis and results in both of a chromosome pair going to one of the two new daughter cells, both daughter cells have the incorrect number of chromosomes. Also, at times, an extra section of a chromosome is replicated and passed to a daughter cell. Such errors in chromosome replication and separation are called nondisjunction. Usually such flawed chromosome divisions are fatal to the offspring, and hence they are not passed on through the generations, as are hemophilia and blue eyes. However, in some situations, such as those involving smaller amounts of chromosomal material, afflicted individuals live.

Nondisjunction in the Twenty-Third Chromosome Pair

A known defect originating during gametogenesis is nondisjunction in the sex chromosomes, in which the twenty-third pair of chromosomes fails to separate, and both chromosomes go to one of the daughter cells during meiosis. Four abnormal zygote types that may live to birth form as a result of nondisjunction of one of the sex chromosomes during oogenesis or spermatogenesis.

One type of abnormal human zygote resulting from disjunction has an XO chromosomal pattern (where O denotes no chromosome). These individuals appear as short females who do not mature at puberty. Also, they often suffer from other congenital abnormalities. This defect is called Turner's syndrome. The YO pattern has not been discovered, suggesting that this condition always kills the fetus. Yet another abnormal human zygote carries an XXX chromosomal pattern. These individuals are known as "superfemales." It is presently unknown how this chromosomal pattern affects the development of "superfemales."

Another abnormal human zygote resulting from disjunction has an XXY sex chromosomal pattern. These individuals appear as males, and often they are mentally retarded. This defect is called Klinefelter's syndrome. The fourth abnormal condition results when a normal X bearing chromosome is fertilized by a YY sperm, formed by nondisjunction during spermatogenesis. This produces an XYY male who is usually over six feet tall and highly aggressive. Studies have shown that a percentage of inmates in institutions for the criminally insane carry this chromosome abnormality.

Autosomal Nondisjunction

Nondisjunction of other chromosomes also is known to occur. The twenty-two chromosomes in man not related to sex determination are called autosomes, hence the term autosomal nondisjunction. The most common autosomal abnormality results from nondisjunction of the twenty-first autosome pair. The result is a mentally retarded, physically altered child said to be suffering from Down's syndrome, or mongolism. About 95% of all cases of Down's syndrome occur because the child has three, rather than the normal two chromosomes in pair twenty-one. This is called trisomy 21, and it usually results from a mistake in cell division of either the sperm or egg. The incidence of trisomy 21 increases dramatically with the age of the mother. Children born of mothers who are forty-eight years of age have a one in twelve chance of being mongoloid, but the possibility of suffering from this disorder when born of a mother under the age of thirty is less than one in nine hundred.

Sometimes children are born who have an extra piece of a twenty-first chromosome attached to another chromosome. The twenty-first chromosome has attached, or translocated, a piece of itself to another chromosome. Such an affected individual has forty-six chromosomes plus an extra little piece of a third chromosome number twenty-one. This is known as translocation Down's syndrome, and it occurs in about 4% of all Down's syndrome cases.

A very rare type of Down's syndrome is called mosaicism. Mosaicism is not as serious as other Down's syndrome disorders, because only some of the child's cells have forty-seven chromosomes, while other cells have the normal forty-six. This can result when a nondisjunction error of the twenty-first chromosome pair occurs in an early cell division of the fertilized egg.

20. In which cells may nondisjunction occur? ________________________

____

____

21. What happens to cause Turner's syndrome? ________________________

____

____

22. Of the nondisjunction disorders discussed above, which syndromes occur due to nondisjunction of the egg, and which due to nondisjunction of the sperm? Which might be due to nondisjunction of either the egg or the sperm?

____

____

____

____

____

23. Which of the syndromes occur due to nondisjunction of autosomes? ________________________

____

____

____

24. Which of the syndromes occur due to nondisjunction of the sex chromosomes? ____________________

____

____

Resources

Genetics Learning System. *X-Linked Disorders*, EP 2226, *Nondisjunction and Translocation*, EP 2219, *Sex Chromosome Disorders*, EP 2220, and *Autosomal Abnormalities*, EP 2221. Each is a slide program with cassette produced by the School of Medicine, University of New Mexico.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

autosome

incomplete dominance

nondisjunction

X-linkage

Review

18. Incomplete Dominance, Sex-linked Inheritance, and Nondisjunction

Name ______________________

Date ______________________

Matching

______ 1. Nondisjunction

______ 2. Morgan

______ 3. Autosomal disorder

______ 4. X-linked trait

______ 5. XX

______ 6. Incomplete dominance

______ 7. YO

______ 8. XXY

______ 9. Translocation

______ 10. XO

A. Klinefelter's syndrome

B. Down's syndrome

C. Female

D. ab

E. Fruit flies

F. 46 chromosomes + another piece

G. Turner's syndrome

H. Homologous chromosomes do not separate

I. Hemophilia

J. Lethal

Solve the following problems

11. A plant with red flowers was crossed with a plant with white flowers. Only pink-flowered plants resulted. How can this be?

12. If two of the pink-flowered plants in question #11 were crossed and twenty-four flowers resulted, what color of flowers would the plants have, and in what ratio?

13. A normal man whose father was colorblind marries a normal woman whose father was colorblind. They have four children. What are the chances that these children will be colorblind?

14. Mr. and Mrs. Zingaro have three children, two girls and a boy. The boy has hemophilia. The Zingaros insist that no one else in their families has hemophilia. What must be the genotype of the parents?

15. In the space provided below, create your own dihybrid cross in which both characteristics are incompletely dominant.

19. Laboratory

Blood Typing

When you have completed this laboratory you should be able to:

1. Understand the concept of multiple alleles.
2. Test blood to determine its blood group.
3. Test blood to determine its Rh factor.

Multiple Alleles

Sometimes a mutation occurs at a particular spot, or locus on a chromosome, and the mutation affects only one gene of a pair. Before the mutation there would have been two alleles at that particular locus. After the mutation, believed to occur usually during replication, there will be three alleles, the original two genes, plus a mutated gene on one of the successor chromosomes. There are many examples of multiple alleles, such as those which govern hair and eye color in humans.

Blood type is an inherited multiple allelic trait. Although your blood type is controlled by two genes, there are three alleles for human blood. The symbols are I^A, the gene for blood type A, I^B, the gene for blood type B, and i, the gene for blood type O. Any given individual inherits only two of these genes, but there are three in the human population. These three alleles give six possible genotypes and four possible phenotypes. Genes I^A and I^B lack dominance over each other, while i is recessive to both I^A and I^B. Therefore, a person with genotype I^AI^B has blood type AB, and a person with genotype I^Ai has blood type A. Two subgroups of type A blood have been discovered, but for the purposes of this laboratory, these variants will not be considered.

In any mixed population, approximately 45% of people have blood type O and 40% blood type A. Approximately 10% have blood type B and 5% blood type AB. However, this can vary considerably depending upon the population mixture. For example, 91% of full-blooded American Indians have type O blood, whereas only 22% of Armenians have Type O blood. Chinese test as 10% type AB blood, whereas type AB blood is not found at all among American Indians.

Agglutinogens

Blood types are classified on the basis of the presence or absence of two agglutinogens (chemicals that coagulate substances), A and B, found in the red blood cells. Both of these agglutinogens are present in type AB blood, and both are absent in type O blood. When type A blood is added to type B blood, it clumps (coagulates). Therefore, the plasma, or liquid portion, of type B blood contains a chemical, called an antigen, on the surface of its red blood cells which clumps "A" cells. This chemical is known as anti-A serum. Conversely, anti-B serum is extracted from the blood of a person with type A blood.

It is now known that all the ABO blood groups have another antigen, a weak antigen called the H antigen. At first it was thought that people with blood group O did not have any antigens. The production of H antigen is controlled by a gene locus separated from that of the ABO locus. There is also a recessive allele, h, for the H antigen, but the homozygote hh is very rare. It is called the Bombay phenotype, after the location where it was discovered.

Transfusions

It is extremely important to provide the right kind of blood for transfusions. It should be the same blood type as the recipient's blood type. If particular types are mixed, death could result. Clumped blood cells accumulate in the recipient's body, become trapped in capillaries, rupture, and clog vital organs. Type AB blood recipients can receive blood from all donors, while group O blood donors, known as universal donors, can donate blood to any of the other blood groups because their blood lacks both anti-A and anti-B serum.

The Rh Factor

Many other human blood characteristics were discovered after learning of ABO blood classification. One of the best known of these is the Rh antigen. The Rh antigen is named for the rhesus monkey in which it was first detected. Today more than forty human Rh antigens are known, of which the D antigen is the strongest. We will assume for the purposes of this laboratory that the Rh factor is inherited as a simple dominant characteristic. Nearly 90% of people have the Rh antigen in their blood, and they are termed Rh positive. The others do not have the antigen and are termed Rh negative. Rh negative blood, when exposed over time to D antigen, or other Rh positive factors, will be destroyed. Rh incompatibility between mother and fetus can lead to birth defects or death of the fetus.

In this laboratory you will test a sample of blood to determine its ABO grouping, as well as its Rh characteristic.

Pre-lab

Supplies needed:

Materials

2 toothpicks
anti-A serum
anti-B serum
anti-D serum
blood test card
blood lancet
alcohol swabs
cellophane tape

Special preparations

1) Blood test cards are available in many forms. Some are wallet sized, while others are designed as labels which the student can stick to other surfaces. Students also can make their own cards, using heavy paper with one side being non-absorbent.

2) Use only sterile alcohol swabs and disposable lancets. As an alternate to personal blood testing, use synthetic blood available from biological supply houses.

3) 5 ml. vials of sera are ample for classes of thirty.

4) It is smart to have adhesive bandages readily available in case of accidents and also to inform the school nurse of the day that students will perform this laboratory. Sometimes students faint at the sight of blood. It is also prudent to verify, before beginning, that there are no hemophiliacs in the class.

Time Required

The blood typing laboratory requires one laboratory hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Put one drop each of anti-A serum, anti-B serum, and anti-D serum in the circles so labeled on your blood typing card. To avoid cross contamination of sera, always replace the cap on one serum bottle before removing the cap from a second bottle. Avoid touching the drop from one serum bottle with the dropper from a different serum bottle. See figure one below for an example of a blood typing card.

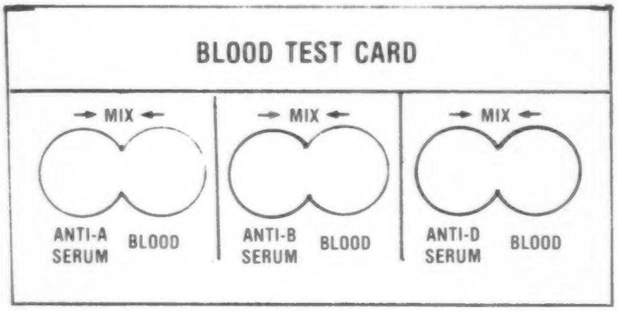


Figure 1

NOTE: If synthetic blood is used, delete steps B, C, and D.

B. Scrub the tip of a middle finger with an alcohol swab. Remove a disposable, sterile lancet from its wrapper. Firmly press the middle finger about one centimeter from the fingertip with the thumb of the same hand. Alternatively, you can have your partner squeeze your finger with one hand.

C. Quickly puncture your clean finger with the lancet. Alternatively, if needed, you can have your partner do this for you while you hide your eyes. Discard the lancet.

D. Quickly press out one drop of blood and wipe your finger with an alcohol swab. Squeeze out more blood, and place one drop in each of the three circles labeled blood on your blood test card. Be careful not to put too much blood in each spot, because you need to see the reaction between the blood and serum, and too much blood makes everything so red that you cannot see the test results. Wipe any excess blood from your finger with an alcohol swab. In most cases, bleeding will stop within two minutes. If you continue to bleed, cover your finger with an adhesive bandage.

E. Use one end of a toothpick to mix one drop of blood with the anti-A serum. Break the toothpick and discard it. Use another toothpick to mix another drop of blood with the anti-B serum. Use the opposite end of the toothpick to mix the third drop of blood with the anti-D serum. Break the toothpick and discard it. Be careful not to cross contaminate the samples because the slightest mixing will ruin your test results.

F. Gently move the blood typing card back and forth for two or three minutes. Be careful to keep each mixture within its circle.

G. Examine the anti-A, anti-B, and anti-D mixtures for any signs of blood granulation, or the clumping of blood into tiny sand-like particles. Anti-D serum takes as long as seven or eight minutes to produce blood granulation. Therefore, even if the anti-A and anti-B serums have reacted, wait patiently for anti-D test results.

What is your blood type according to this test? If agglutination has occurred in only the anti-A serum, you are type A blood. If it has occurred in only the anti-B serum, you are type B blood. If it occurred in both anti-A and anti-B serum, you are type AB blood. If granulation occurred in neither, you are type O blood. If agglutination occurred in anti-D serum, you are Rh positive, and if it did not occur, you are Rh negative. You must look at the anti-D test result carefully, because it not only takes longer than the other two tests, but it also is a weaker reaction.

Check with your parents, guardian, or doctor to verify these test results.

H. Determine your blood type. Put your blood type and Rh factor results in ink on the upper right hand corner of your card. Also, write your name on the card.

1. What is your blood type? ______________________________

I. Allow the card to completely dry. This may take up to two hours. When the card is completely dry, cover the test area with a piece of cellophane tape. This protects the blood test so that it can be carried in your wallet for instant blood type identification, if you performed a personal blood test. A card like this could save your life if you ever need an immediate and unexpected blood transfusion.

J. Compare your blood type results with those of your classmates. This is done easily if everyone writes their blood type in a chart on the blackboard before the end of class.

2. How many students are in your biology class? ______________________________

3. Using the information gathered from the other students, complete the figure two chart below.

Number and Percentage of Each Blood Type in Biology Class		
Type	**Total Number of Students with each Type**	**Percentage with each Type**
O^{+}		
O^{-}		
A^{+}		
A^{-}		
B^{+}		
B^{-}		
AB^{+}		
AB^{-}		

Figure 2

4. How do your class percentages for blood types compare with the averages for a mixed population? If they differ, how?

____

____

Resources

Carolina Biological. *Human Blood Groups.* #52-2700, filmstrip with cassette, or, #48-1232, slide set with cassette.

Race, R. R. and R. Sanger. *Blood Groups in Man.* Blackwell Scientific: Oxford, England, 1973.

Watkins, Winifred, M. "Blood-group Substances," *Science*, V. 152, 1966.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

blood type   Rh factor

Review

19. Blood Typing

Name______________________________

Date______________________________

Multiple choice: more than one answer is possible for some questions. List all possible answers.

______ 1. Which of the following genotypes is found in people possessing blood type A?
- a. I^Ai
- b. I^Bi
- c. I^AI^A
- d. ii

______ 2. Which gene is recessive to any other blood type allele?
- a. I^A
- b. I^B
- c. i
- d. I^D

______ 3. The universal donor is
- a. Type A
- b. Type B
- c. Type AB
- d. Type O

______ 4. Those people who possess blood type B
- a. can synthesize agglutinogen A
- b. can clump or agglutinate type A blood
- c. can donate blood to people with type A blood
- d. can donate blood to other people with type B blood

______ 5. Blood type AB is called the universal recipient because
- a. it can be transfused into persons of every blood type
- b. people who have type AB blood can accept transfusions from people of every blood type
- c. it possesses B agglutinogens
- d. it possesses A agglutinogens

______ 6. When multiple allelic forms of a certain gene exist, how many alleles for that trait may an individual possess?
- a. each individual can possess as many alleles as there are for that trait
- b. each individual can possess only two allelas even though many are possible
- c. each individual can possess only three alleles even though many are possible
- d. each individual can possess only one even though many are possible

______ 7. Multiple alleles are found
- a. on heterogeneous spots of a chromosome
- b. at the same location on homologous chromosomes
- c. at the last gene group on every chromosome
- d. at the first gene position on every chromosome

______ 8. The blood type that is always evidence of a homozygous condition is
- a. A
- b. B
- c. AB
- d. O

Suppose the identities of two newborn babies are confused in the hospital nursery, something that rarely happens. In an effort to determine the parentage of each baby, the blood types of the babies and the parents are determined.

Baby 1	Type O
Baby 2	Type A
Mrs. Brown	Type B
Mr. Brown	Type AB
Mrs. Smith	Type B
Mr. Smith	Type B

______ 9. Baby 1 can belong to only
a. Mr. and Mrs. Brown
b. Mr. and Mrs. Smith

______ 10. The genotype of both Mr. and Mrs. Smith can be
a. $i^{A}i$
c. $I^{B}I^{B}$
b. $I^{B}i$
d. $I^{A}I^{B}$

20. Exercise

Pedigree Studies and Human Genetic Traits

When you have completed this exercise you should be able to:

1. Prepare and read pedigree charts.
2. Calculate expected genotypes for individuals shown in pedigrees.
3. Study the inheritance of some human genetic traits.
4. Determine the frequency of selected traits in a given population.

Pedigrees

A pedigree summarizes ancestry. All living things, including humans, have pedigrees. The term is not reserved for show dogs and race horses alone. A pedigree can be shown in several different forms, and during this exercise you will consider two types of pedigree charts.

Pedigree Charts

One type of pedigree is a diagram which shows the occurrence and phenotype of a particular genetic trait from one generation to the next. Genotypes for individuals appearing in such pedigrees usually can be determined when one understands inheritance and probability. Figure one below is an example of such a pedigree chart.

Key:

Symbol	Meaning
□	Male
○	Female
■ ●	Affected Individual
□ ○ † †	Stillbirth
□ ○	Fraternal Twins

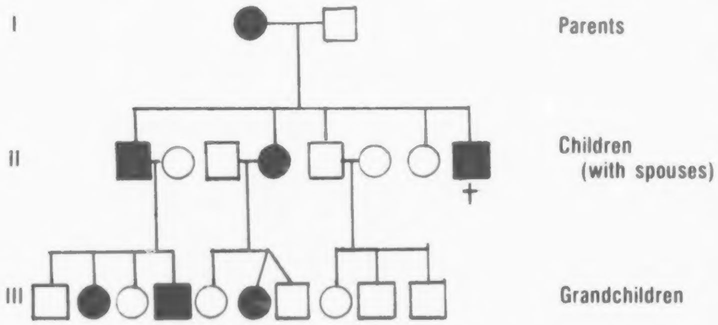


Figure 1

Notice how the marriage line in the I, or parent generation is drawn. Also notice how the children lines in II and III, or the F_1 and F_2 generations are drawn.

1. In the space below, diagram your own pedigree, using your grandparents as the I generation, your parents as the II generation, and yourself and any siblings (brothers and sisters) as the III generation. Do not record any hereditary traits. Instead, write the name of the individual below their square or circle in the diagram. Again, if there is a problem in tracing your personal ancestry, record the pedigree of someone who is not in your biology class.

Genealogy Charts

Another way to show pedigree is through a genealogy chart, which lists ancestry by individual name and other pertinent information, such as birth date and place. An example of such a genealogy chart is found in figure two on page 183.

2. Complete the chart shown in figure two as completely as you can. Ask for help from your parents or guardians, as well as anyone else who might be familiar with your genealogy. If there is a problem in tracing your personal ancestry, record the genealogy of someone who is not in your biology class.

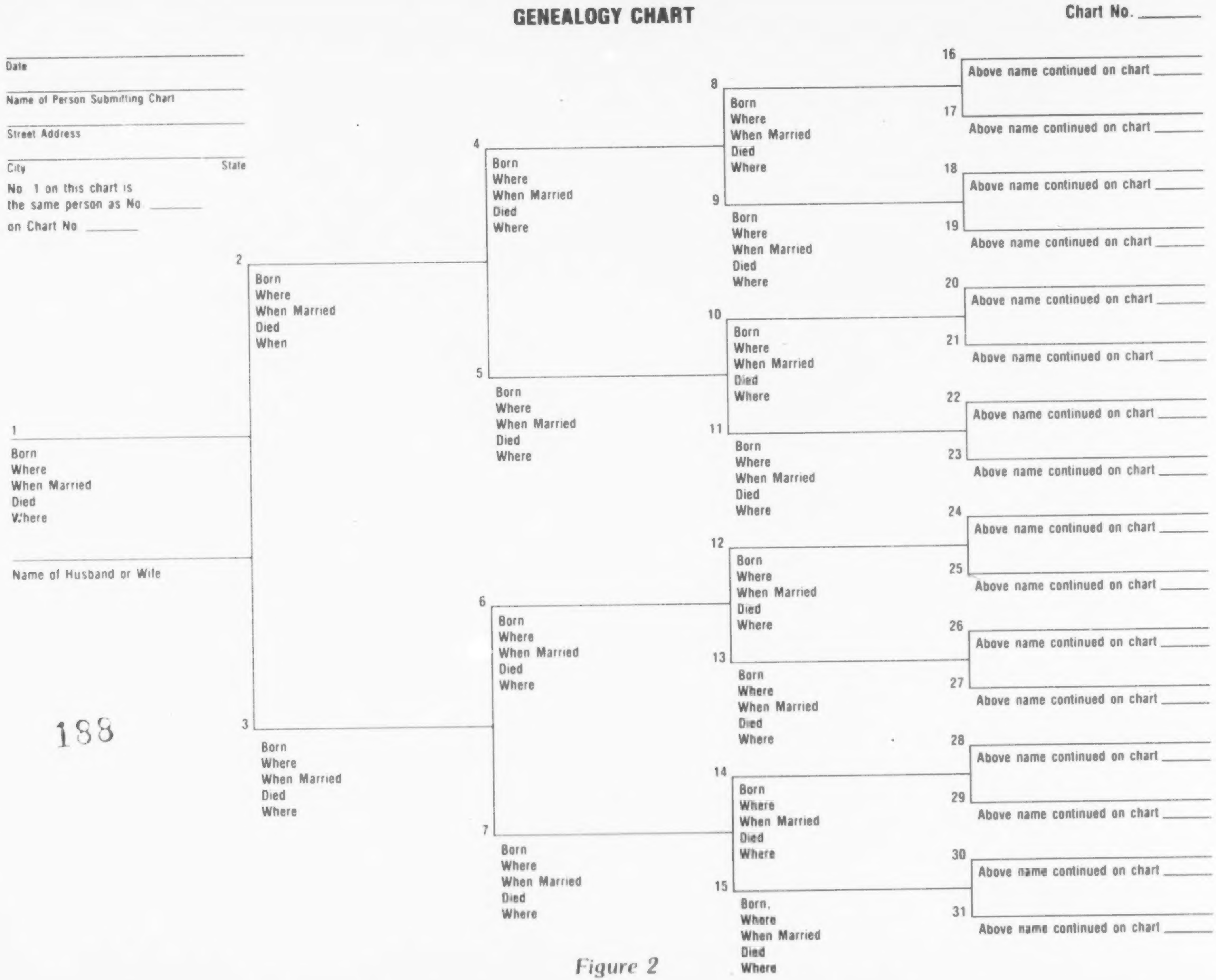
Human Genetic Trait Frequencies

Let us first consider some of the human genetic traits which you studied in earlier exercises. For example, the inheritance of hemophilia can be diagrammed on a pedigree chart. It is a classic example of a recessive allele transmitted on the X chromosome. Studies of hemophilia in families were first done on the royal houses of Europe.

Hemophilia

Queen Victoria, who was undoubtedly a carrier for hemophilia, married Prince Albert. They had nine children. They were as follows:

Princess Victoria married Frederick II, Emperor of Germany. Their offspring constituted the German royal house, plus marriages into the royal families of Greece and Rumania. No one of this line showed evidence of hemophilia.



GENEALOGY CHART

Chart No. ______

Date ______

Name of Person Submitting Chart ______

Street Address ______

City ______ State ______

No. 1 on this chart is the same person as No. ______

on Chart No ______

1 ______
Born
Where
When Married
Died
Where

Name of Husband or Wife ______

2 ______
Born
Where
When Married
Died
When

3 ______
Born
Where
When Married
Died
Where

4 ______
Born
Where
When Married
Died
Where

5 ______
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When Married
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13 ______
Born
Where
When Married
Died
Where

14 ______
Born
Where
When Married
Died
Where

15 ______
Born,
Where
When Married
Died
Where

16 ______
Above name continued on chart ______

17 ______
Above name continued on chart ______

18 ______
Above name continued on chart ______

19 ______
Above name continued on chart ______

20 ______
Above name continued on chart ______

21 ______
Above name continued on chart ______

22 ______
Above name continued on chart ______

23 ______
Above name continued on chart ______

24 ______
Above name continued on chart ______

25 ______
Above name continued on chart ______

26 ______
Above name continued on chart ______

27 ______
Above name continued on chart ______

28 ______
Above name continued on chart ______

29 ______
Above name continued on chart ______

30 ______
Above name continued on chart ______

31 ______
Above name continued on chart ______

Figure 2

King Edward VII of Great Britain continued the British royal house, and offspring married into the Norwegian royal family. No one of this line showed evidence of hemophilia.

Princess Alice married Louis, Grand Duke of Hesse. They had three children. The first was Princess Irene who married Prince Henry of Prussia, and they in turn had three boys, two of whom were hemophiliacs. The second was Prince Frederick, who was a hemophiliac and did not marry. The third was Alexandra who married Nicholas II, Tzar of Russia. They in turn had five children, four girls and a boy. The boy had hemophilia.

The next child of Queen Victoria was Alfred, Duke of Edinburgh, whose progeny intermarried with the royal houses of Greece and Yugoslavia. No one of this line showed evidence of hemophilia.

Princess Helena bore children who did not marry into royal houses.

Princess Louise had no children.

The children of Arthur, Duke of Connaught, intermarried with the royal houses of Sweden and Denmark. No one of this line showed evidence of hemophilia.

Leopold, Duke of Albany, was a hemophiliac who married Princess Helena of Waldeck. They had one daughter, Princess Alice who married the Earl of Athlone, and they in turn had three children, one girl and two boys, and one of the boys was a hemophiliac.

Princess Beatrice married Prince Henry of Battenberg. They had four children. The first was Queen Ena who married Alfonse XIII, King of Spain. They had seven children, two girls and five boys, and two of the boys suffered from hemophilia. The second was Lord Leopold Mountbatten who was a hemophiliac. The third was Lord Maurice Mountbatten who also was a hemophiliac. The fourth was the Marquess of Carisbrooke who was normal for hemophilia.

3. Diagram, on the following page, the pedigree of the offspring of Queen Victoria and Prince Albert. Your chart should be in a form similar to that shown in figure one, with the hemophiliacs indicated. Where possible name each person below their symbol.

Sometimes a genetic trait is not potentially lethal, but it makes the individual obviously different from others. You have studied some of these surface traits in previous exercises. For example, dark hair is dominant over blond hair, and red hair is recessive to both. Abundant body hair is dominant over minimal body hair, nearsightedness and farsightedness are dominant over normal vision, large eyes are dominant over small eyes, and long eyelashes are dominant over short eyelashes. Let us consider a trait which changes the size of an affected individual.

Brachydactyly

Brachydactyly is an inherited trait in which the individual is missing one joint in their fingers and toes. Therefore, the fingers and toes appear shorter and stubbier than normal. Also, the individual is shorter than average. Women average 1.5 meters (5 feet) in height, and men average 1.55 meters (5 feet, 2 inches) in height. Brachydactyly is not found in the general population of the United States, but it is found with some frequency among people native to the Pennsylvania-Maryland area. This suggests that a mutation occurred among the population of that region in fairly recent times. This trait appears to have no detrimental effects on those who show the trait.

In Pennsylvania, during the 1850's, a very short man married a normal-sized woman. These two were ancestors of a colleague of the author. The Pennsylvania couple had seven children. They were as follows.

Lizzie was described by her descendants as being very, very short. She married Harry, and they had two children, very short Wilson and very, very short Mabel, as they were called within the family. Wilson married Clara, and they in turn had two children, tiny Webster and very, very short Grace. Tiny Webster married a reasonably tall woman, and they had normal-sized Barbara and really little Webster. Grace married Charles, and they had two boys, normal-sized Albert and very short William. Normal-sized Albert married and had two normal-sized daughters. Very short William married and had a normal-sized daughter and a very short boy.

The second child, Carrie, was very, very short. She married Will, and they had a normal-sized daughter, Elizabeth, and also two normal-sized boys, Bob and George. Elizabeth married and had two girls and a boy, all of whom were normal, as were their offspring. Bob married and had two normal-sized daughters. George married and had a boy and a girl, both of whom were normal-sized.

Jonas was very short. He married Beulah, and they had very, very short Ethel. Ethel married and had Punky, who also was very short.

The fourth child, Effie, was very, very short. She married Harry, but they had no children.

Uncle Brother, as he was known within the family, was a normal-sized man. He married Grace, and they had no children.

Sallie was very, very short. She married George, and they had one child, George, who was very short. George married and had two normal-sized daughters. They also married and had normal-sized offspring.

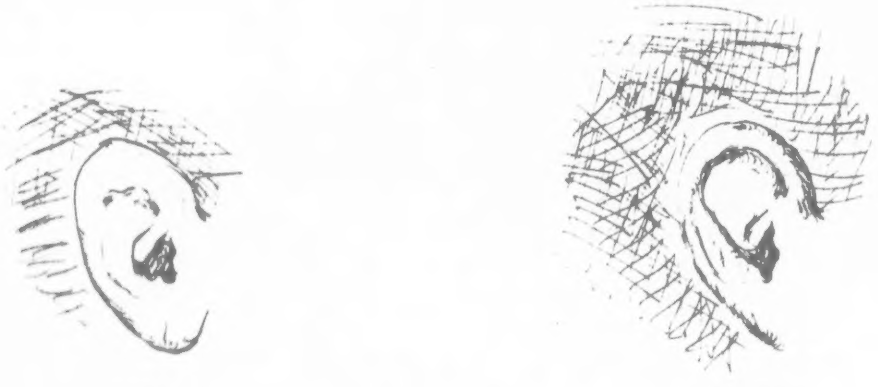
Mamie was a normal-sized woman who never married.

4. Diagram, in the space provided on the following page, the pedigree of the offspring of the very short man and the normal-sized woman who married during the 1850's in Pennsylvania. Your chart should be in a form similar to that shown in figure one, with those affected by brachydactyly indicated. Where possible name each person below their symbol.

Other Human Traits

Let us now consider a few simple human traits present in normal populations. Read the short description for each trait listed in the following paragraphs. Each of you can then determine from the description whether you carry a dominant gene for the trait, or whether you are homozygous recessive for the trait.

Attached earlobes: the earlobes of most people hang free. This characteristic is controlled by a dominant gene (E). When a person is homozygous recessive for the trait, the earlobes are attached directly to the sides of the head. See figure three below.



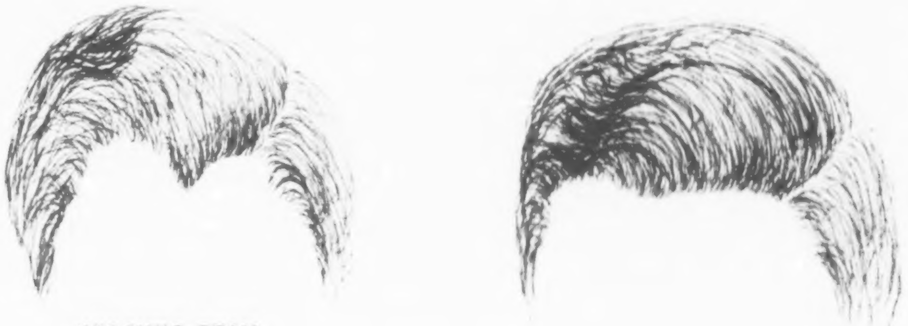
FREE

ATTACHED

Ear Lobes

Figure 3

Widow's peak: in some people the hair line drops downward and forms a distinct point in the middle of the forehead. This is called a widow's peak. It results from a dominant gene (W). See figure four below.



WIDOW'S PEAK

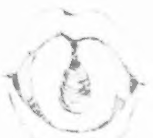
NORMAL

Hair Lines

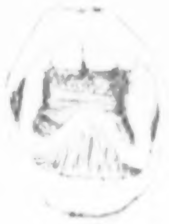
Figure 4

Tongue rolling: some people can roll their tongue into a U-shape when the tongue is extended from the mouth. This results from a dominant gene (R). Non-rollers (rr) cannot do this. See figure five below.

Tongue folding: a few people can fold their tongue backward, without pressing it against the upper teeth. This is a very rare (f) trait, occurring in the human population at a frequency of less than one per thousand individuals. See figure six below.



Tongue Rolling
Figure 5

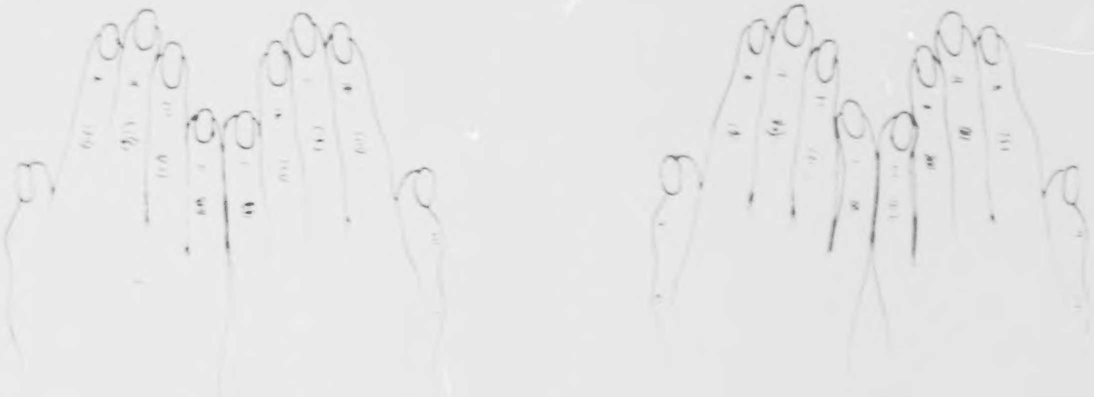


Tongue Folding
Figure 6

PTC tasting: PTC stands for phenylthiocarbamide. About seven of every ten people taste PTC as a salty, sweet, sour, or bitter substance. To others, PTC is tasteless. The ability to taste PTC is a dominant trait (T).

Sodium benzoate tasting: sodium benzoate is sometimes used as a food preservative, although its safety is debated. Some people can taste this substance (S), while others can not.

Bent little finger: a dominant gene (B) causes the last joint of the little finger to bend inward toward the fourth finger. Lay both hands flat on a table, relax your muscles, and note if you have a bent or a straight little finger. See figure seven below.



Straight

Bent

Figure 7

Hitchhiker's thumb: this is a recessive trait. People who are homozygous recessive for the trait (hh) can bend the distal segment of the thumb backwards, so that an angle of sixty degrees is made between the axes of the two thumb segments.

5. Determine which of the traits listed above you phenotypically show. Record your findings in the left column of the figure eight chart below, using the capital or lower case letters provided with each description.

NOTE: Your instructor must provide PTC taste papers and sodium benzoate taste papers to determine two of these traits.

PTC (phenylthiocarbamide) taste papers may be purchased, or made by gradually dissolving 500 mg. of phenylthiocarbamide in 1 liter water. At room temperature, this takes about 24 hours. Soak sheets of filter paper in this solution and hang to dry.

Sodium benzoate taste papers may be purchased, or made by soaking filter paper in a 0.1% solution of sodium benzoate and water and hanging to dry.

Your Genetic Traits					
Trait	**Your Phenotype**	**Class Results**			**Percent with Your Trait**
		Dominant	**Recessive**	**Ratio**	
Ear Lobes					
Widow's Peak					
Tongue rolling					
Tongue folding					
PTC tasting					
Sodium benzoate					
Bent little finger					
Hitchiker's thumb					

Figure 8

6. Record the number of dominant and recessive phenotypes to be found in your biology class, for each of the eight traits listed in figure eight. This data is most easily collected by copying the chart on a blackboard and having each member of the class record their traits in the chart for all to copy. Enter these group findings in the figure eight chart.

7. Determine the ratio of dominant to recessive traits recorded for the class as a whole, and also determine the percent frequency in the class for your personal traits. Record this information in the figure eight chart.

8. How many students are in your biology class? ____________________

9. How does the frequency of your personal traits compare with the frequency of these traits found in the class as a whole?

10. Determine if the traits you possess are similar to those of your siblings and parents. Go home from class with enough PTC and sodium benzoate taste papers to test your entire family. Record this information in a pedigree chart in the space provided below. If there is a problem in tracing your personal genetic traits, record the traits of someone who is not in your biology class.

Resources

Prentice Hall Media. *Fundamental Principles of Genetics: the Hows and Whys of Inheritance.* #30937-910, a set of 4 sound filmstrips with workbook/study guides.

Prentice Hall Media. *Special Topics in Genetics.* #30939-910, a set of 3 sound filmstrips with workbook/study guides.

Review

20. Pedigree Studies and Human Genetic Traits

Name______________________________

Date_______________________________

Solve the following problems

1. In the pedigree chart, figure nine below, there are individuals who show the trait for brachydactyly. These individuals are shown as a darkened circle or square. Write the genotypes for each individual under their symbol in the pedigree chart, and complete the chart to the left with the meaning for each different symbol. Let the symbol "B" represent the trait for brachydactyly on the pedigree.

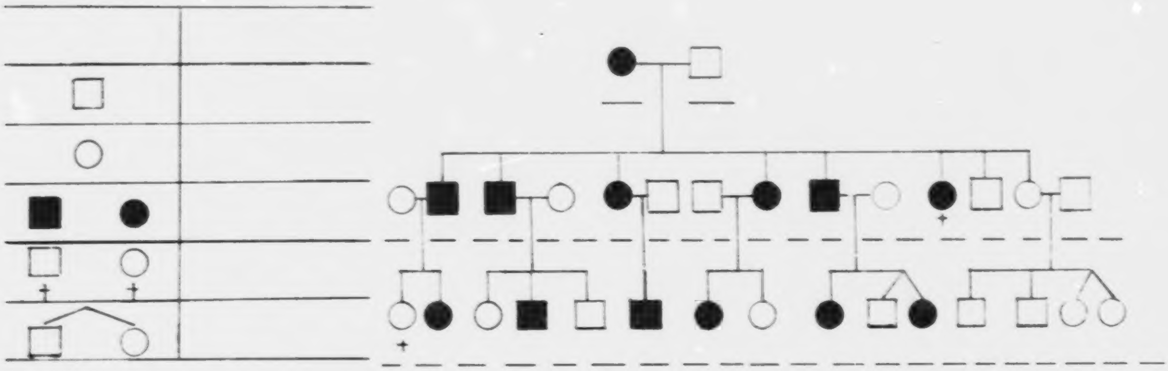


Figure 9

2. In the pedigree chart, figure ten on the next page, there are individuals who show the trait for attached earlobes. These individuals are shown as a darkened circle or square. Write the genotypes for each individual under their symbol in the pedigree chart, and complete the chart to the left with the meaning for each different symbol. Let the symbol "e" represent the trait for attached earlobes on the pedigree.

3. Cystic fibrosis is a recessive hereditary disorder. Sally has cystic fibrosis, and she is normal for brachydactyly. Her parents are normal for both traits. Medication has prolonged her life, and she is married to George. There has never been a case of cystic fibrosis in George's family. He does, however, have brachydactyly, as does his father. Sally and George would like to have children, if the children had neither cystic fibrosis nor brachydactyly.

If you were a genetic counselor, what would you tell them? Show all genotypes, explain their phenotypes, and draw a Punnett square as part of your answer in the space provided below.

Key:

Symbol	Meaning
□	
○	
■ ●	
□ + ○ +	
□ ○	

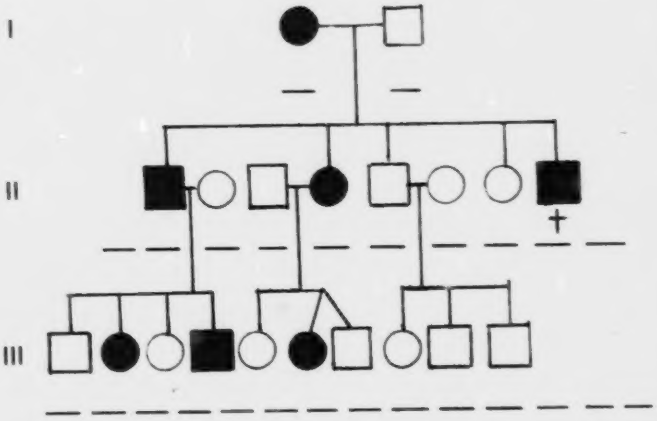


Figure 10

21. Laboratory

Natural Selection

When you have completed this laboratory you should be able to:

1. Discuss the work of Erasmus and Charles Darwin.
2. Demonstrate the impact of environment on natural selection.
3. Observe the interrelationship of predator and prey in natural selection.

Erasmus Darwin

Intellectuals during the eighteenth century began to consider ideas about the origin and continuity of species not based on a literal interpretation of the creation account given in the *Bible*. The idea of evolution, that species change over time, was familiar to students of natural history, but the evolutionary point of view was expressed with caution because it challenged orthodox religion. Conservatives believed that the world had been created in six earth days and that all known species had then come into existence and that they were unchangeable, or immutable, as they phrased it.

The spread of European empires over the face of the earth, with the discovery of vast numbers of new and unusual species and the unearthing of large numbers of fossilized, extinct species, forced naturalists to compare and explain this unimagined diversity. Farmers had conducted sophisticated breeding experiments with domestic animals and plants and knew instinctively that species can undergo great change through the generations. As the eighteenth century progressed, the concept of evolution had spread, with, for example, an American printer, experimenter, and politician named Benjamin Franklin referring to man as a "tool-making animal." Vague ideas about evolution, however, remained incomplete and hesitant.

It was in these circumstances, between 1789 and 1803, that Erasmus Darwin wrote a series of works, in prose and verse, which stated his views on evolution. Erasmus Darwin was one of the most celebrated personalities in the England of his time. A physician, a philosopher, and a poet, Erasmus Darwin attempted to answer two basic questions on evolution. First, are all living things descended by transformation from a single ancestor? Second, if so, how could they have been transformed? He attempted to provide a theoretical explanation of mechanisms which would account for change in species over time, as applied in farm breeding and as seen by collectors around the world.

Erasmas Darwin assembled the evidence of embryology, comparative anatomy, systematics, geographical distribution, and, in so far as man is concerned, the facts of history and medicine. He especially noted the differences between the fauna of the New and Old Worlds. Erasmas originated, at least in embryonic form, almost every important idea that has since appeared in evolutionary theory. He theorized that competition and selection cause change, that overpopulation is an agent that enhances competition, that this is true in plants as well as in animals, that in animals another important mechanism is competition between males for breeding opportunities with females, and, that fertility and susceptibility to disease, being hereditary, are also mechanisms of evolution. He employed the Comte de Buffon's theory of the inheritance of acquired characteristics to suggest that inheritance might be both direct and indirect, that the effects of use and disuse might be inherited and cumulative over time.

Within two years of the death of Erasmus Darwin the word "Darwinian" was coined to describe his ideas on evolution. Five years after his death his grandson, Charles Darwin, was born. Four years later Thomas Malthus developed one of Erasmus Darwin's ideas, that on population pressures, into his *Essay on Population*. Nine years later Chevalier de Lamarck expounded a theory of evolution based on the Darwinian concept of the inheritance of the effects of use and disuse. Nearly sixty years later Charles Darwin amplified the concept of sexual selection. Another of his grandsons, Francis Galton, developed ideas on human breeding and invented the study of eugenics. Not one of these authors adequately acknowledged Erasmus Darwin as the creator of the basic ideas with which they worked. Erasmus was a profoundly creative man ahead of his time. Of all his successors Charles Darwin stated most clearly the entire concept of evolution as Erasmus Darwin envisioned it. Charles built on his grandfather's seminal ideas, adding masses of evidence to corroborate the concepts. He also wrote well and was lucky, in that the reading public was ready to accept evolutionary theory.

Charles Darwin

On December 27, 1835 Charles Darwin set sail aboard the H.M.S. Beagle for a five year voyage around the world. The H.M.S. Beagle had been directed to survey and chart the coastlines of South America. Charles Darwin joined the cruise as an unpaid naturalist. He was then a twenty-two year old college-dropout who had failed to complete courses in both medicine and the clergy. As the voyage of the Beagle continued, Darwin became increasingly fascinated with the new life and lands that he visited. He took meticulous notes, made drawings, and collected samples of everything that he saw. This thoroughness was to make all the difference in the formulation of his theories.

Upon his return to England, Charles Darwin settled into the life of a gentleman farmer, considering his notes and collection in his spare time, reading, and corresponding with other naturalists. He married well, reared a family, and conducted breeding experiments. He published in 1845 an account of the voyages of the Beagle in which, among other things, he described his discoveries in the Galapagos Islands. Although his full theory had taken shape over the years, Darwin was a thorough and cautious man who hesitated to publish ideas which were certain to draw attacks. It was only upon learning that a naturalist who had worked both in Brazil and in Southeast Asia, Alfred R. Wallace, was ready to publish ideas strikingly similar to his own that Darwin rushed *On the Origin of Species* to publication. *On the Origin of Species* appeared in November 1859, and its publication constitutes one of the great watersheds in intellectual history. Darwin attempted to show how all living things derive by descent and gradual transformation from common origins many millions of years old.

Natural Selection

A fundamental mechanism of change presented in *On the Origin of Species*, and supported by Wallace, was the theory of natural selection. Natural selection is a process similar to the artificial selection which plant and animal breeders, such as Darwin, were practicing with great success. It is an ongoing natural process, in which members of a species whose modifications suit their environment survive, and those whose modifications place them at a disadvantage die off. Darwin stated five considerations in arriving at his definition of natural selection as the central mechanism of evolution.

First, he stated that all species are engaged in a struggle for survival within their environment. Second, environmental conditions change over time. Third, species also change through continuous modifications. Fourth, through natural selection, modifications best suited to the environment are preserved. And fifth, evolutionary change is the natural selection of successful modifications.

Darwin in later years relied increasingly on a mixed theory of evolutionary mechanism—adding direction to natural selection. Change, he came to believe, was partly limited by the potentialities of the organism, as well as by natural selection after the fact. Darwin was struggling with issues eventually clarified by the discovery of chromosomes and genes. Today's new theories, called neo-Darwinian, further elaborate on this mixed theory of evolution, adding the concept of transformation of genetic plasma. The belief is that chromosomes can be transformed, stretched, or adapted only so far before the result is a new species of organism. To date this remains a theory, because such transformations have not been documented with higher organisms.

In this laboratory you will study how a predator asserts a selective force on the survival of its prey in a given environment. You also will theorize on the variability of a prey species which determines which individuals in the species are more likely to fall prey to a predator. You further will consider how the environment and prey affect the success of a predator.

Pre-lab

Supplies needed:

Materials

1000 lentils
1000 garbanzo beans
1000 dried green peas
1000 navy beans
3 paper cups
1 piece carpeting
knife
fork
spoon
stopwatch or timer

Special preparations

1) Any type of dried legume can be used. The point is to provide the student with different sizes, colors, and shapes. Other possibilities include popcorn, kidney beans, pinto beans, black-eyed peas, and lima beans. The legumes need to be counted out before class, otherwise students will not have enough time to complete the experiment during the period. Students could count out the legumes as a homework assignment the previous night.

2) The carpeting can be obtained from any rug dealer as scrap. Each piece should measure approximately 1 meter to the side.

3) This laboratory is set up for student groups of three. If there are four students per laboratory group, the instructor could add a fourth "predator," such as chopsticks, to the materials list, or use the extra student as a timer and referee. If you add a predator, provide a fourth paper cup. Room is allowed on charts for the addition of an extra "predator."

Time Required

The natural selection laboratory requires one laboratory hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Mix 1000 each of four different types of legumes together on a piece of carpeting. Scatter them randomly over the entire piece. Each student in the laboratory group should choose the utensil with which they are going to "attack" the bean prey. Each student should also have a paper cup.

B. Predators (utensils) forage for their prey as follows:

1). Beans must be picked up by utensils only.

2) Beans must be picked up only one at a time and collected in paper cups.

3). Each utensil-wielding predator must count the number of each kind of bean collected at the conclusion of each foraging session.

Set the stopwatch or timer for five minutes. See how many beans each "predator" can collect, following the above rules exactly, within five minutes. When a legume has been removed from the carpet, it has been "killed."

1. Record your results from step B in the figure one chart below. Also record the results of your laboratory partners, the other predators.

FIRST GENERATION					
Prey Captured By Predator	**Lentils 1000**	**Garbanzos 1000**	**Beans 1000**	**Peas 1000**	**Total Prey Captured**
Knife					
Fork					
Spoon					
Total Captured					

Figure 1

C. Determine predator efficiency by determining how much time each predator will be allowed to forage in the second generation. Use the following formula, where P^k, P^f, or P^s (knife, fork, or spoon) represents the type of predator, B prey caught by a single predator, B_t total prey caught by all predators, and the number 300 the total foraging time in seconds allowed the first generation.

$$p^k \text{ time } = \frac{B}{B_t} \times 300$$

2. Enter the time, expressed in seconds, in the figure two chart below that each predator will be allowed to forage in the second generation.

3. Enter in the figure two chart below the number of prey of each type remaining after initial foraging by the knife, fork, and spoon.

D. Determine how many beans each "predator" can collect in a second generation of foraging, again following the rules as stated in step B, with the modification of reduced time allocated to each predator, as calculated and entered in the figure two chart.

4. Record your results from step D in the figure two chart below. Also record the results of your laboratory partners, the other predators.

SECOND GENERATION					
Predator Foraging Time	**Lentils** _____	**Garbanzos** _____	**Beans** _____	**Peas** _____	**Total Prey Captured**
Knife _____					
Fork _____					
Spoon _____					
Total Captured					

Figure 2

E. Determine how much time each predator will be allowed to forage in the third generation, following the directions for this procedure given in step C, with the modification that the time factor will not be 300 seconds but the number of seconds allowed during the second foraging session.

5. Enter the time, in the figure three chart below, that each predator will be allowed to forage in the third generation.

6. Enter in the figure three chart below the number of prey of each type remaining after the second round of foraging by the knife, fork, and spoon.

F. Determine how many beans each "predator" can collect in a third generation of foraging, again following the rules as stated in step B, with the modification of reduced time allocated to each predator, as calculated and entered in the figure three chart.

7. Record your results from step F in the figure three chart. Also record the results of your laboratory partners, the other predators.

THIRD GENERATION					
Predator Foraging Time	**Lentils** ______	**Garbanzos** ______	**Beans** ______	**Peas** ______	**Total Prey Captured**
Knife ______					
Fork ______					
Spoon ______					
Total Captured					

Figure 3

G. Determine how much time each predator will be allowed to forage in the fourth generation, following the directions for this procedure given in step C, with the modification that the time factor will be the number of seconds allowed during the third foraging session.

8. Enter the time, in the figure four chart on page 198, that each predator will be allowed to forage in the fourth generation.

9. Enter in the figure four chart the number of prey of each type remaining after the third round of foraging by the knife, fork, and spoon.

H. Determine how many beans each "predator" can collect in a fourth generation of foraging, again following the rules as stated in step B, with the modification of reduced time allocated to each predator, as calculated and entered in the figure four chart.

10. Record your results from step H in the figure four chart. Also record the results of your laboratory partners, the other predators.

11. What does the steady reduction in foraging time in the above laboratory symbolize in nature?

FOURTH GENERATION					
Predator Foraging Time	Lentils ______	Garbanzos ______	Beans ______	Peas ______	Total Prey Captured
Knife ______					
Fork ______					
Spoon ______					
Total Captured					

Figure 4

12. Which predator, knife, fork, or spoon, was most successful in obtaining prey? Why? ______

13. Which prey was most successful at evading capture? Why? ______

14. Which predator was least successful? Why?

15. Which prey was picked up the most often, that is, was the least successful? Why? ______

16. In which generation were the relative numbers of successful and unsuccessful groups changing the fastest? Why?

17. What do these results indicate about environmental influences on predator-prey evolution?

18. What do you expect to be the ultimate fate, given enough generations, of those predators and prey which were least successful in your carpet environment? Why?

Resources

Audio Visual Narrative Arts. *Evolution vs. Creation: A Scientific Point of View.* #08367-910, 2 filmstrips and cassettes.

Center for Humanities, Inc. *How Life Survives: Adaptation and Evolution.* #01007-910, either 2 sound-slides or video cassettes.

Cole, Fay-Cooper. "A Witness at the Scopes Trial." *Scientific American*, January 1959.

Darlington, C. D. "The Origin of Darwinism." *Scientific American*, May 1959.

Prentice Hall Media. *Principles of Evolution.* #31417-910, 4 filmstrips and cassettes.

Shell Oil Company. *Exploring the Chasm.* A film.

Sisson, Robert F. "Deception: Formula for Survival." *National Geographic*, 157(3), 1980.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

Darwin

natural selection

Review

21. Natural Selection

Name________________________

Date________________________

Essay

1. What contributions did Erasmus Darwin make to the theory of evolution?

2. Describe the theory of natural selection, as refined by Charles Darwin. What is meant by the "survival of the fittest"? Do you think that this also applies to human populations? Why?

22. Exercise

Fossil Boy

When you have completed this exercise you should be able to:

1. Understand some of the issues involved in the search for man's origins.
2. Evaluate evolutionary changes in hominid species.
3. Examine and measure human skull diagrams.

Early Man

Where does the history of man begin? Scientists have found evidence of organisms existing on earth nearly three thousand million years ago, but man-like creatures have been in evidence less than five million of these years. There is controversy as to whether or not to call some of these "men" or to consider such fossils to be those of extinct primate species. The answer to this issue lies in the definition of what constitutes man, or, how does man differ from primate?

Apparent differences which distinguish man from primate include the ability to walk upright, an enlarged cranial capacity relative to body size, the making and using of tools, speech, and a ritual life. Each one of these differences, however, requires further discussion. For instance, chimpanzees make and use simple tools. How does one really distinguish between the tool using capacity of a chimpanzee that probes for insects with a twig tool and an early man who used chipped rocks or animal bones? What set of physical and cultural changes are necessary before one can call something man? None of these questions is easy to answer, largely because the fossil record is so limited. Several times during the life of the author the "history of early man" has been drastically rewritten due to the discovery of one more fossilized skull or skeleton. This process is likely to continue well into the future, as scientists search for more information covering the approximately five million years that man-like creatures have been on earth.

As of today, two genera of men have been accepted by most scientists, the older *Australopithecus* and the more recent *Homo*. The first *Australopithecus* have been dated at over three and a half million years. The primary distinction between them and primates is a change in the pelvic structure which allowed walking on two feet, thus freeing the hands for eventual manipulation of tools. Although they walked upright, they were small, about the size of today's five year old child, and, in still other respects, they were very different from today's man.

Australopithecus

All specimens in the genus *Australopithecus*, which today has four recognized species, and the earliest species in the genus *Homo* have been found in Africa. Because of this, scientists conclude that man began in Africa. The oldest fossils of *Australopithecus* exhibit sharp and pointed canine incisor teeth, somewhat like those of a dog, but later species show a shrinking of the canines and an enlarging of the molars. *Australopithecus* species exhibit comparatively larger facial areas and smaller brain areas than humans. Most of the *Australopithecus* also exhibit a sagittal crest, or bony ridge across the top of the skull such as that seen in today's gorilla. The sagittal crest holds massive jaw muscles of those primates which crush and grind coarse material. Even though a cartoonist in the January 1987 *Atlantic Monthly* depicted President Ronald Reagan wth a sagittal crest, no modern human has one.

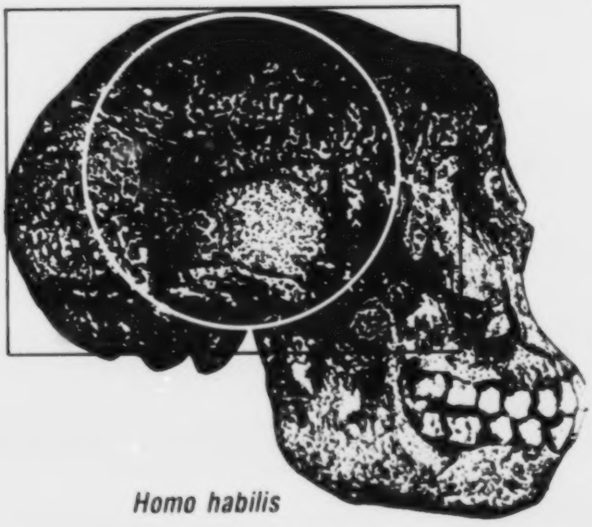
Homo habilis

The earliest species in the genus *Homo* may approach three million years of age. In 1962 Louis Leakey discovered in East Africa a slender-bodied tool-user with a relatively larger but lighter skull than the contemporary

Australopithecus, with which it was proximate. Leaky named this new creature *Homo habilis*. This specimen has been dated at more than two million years. Louis' son, Richard Leakey, found another *Homo habilis* fossil skull in August 1972. This skull, assigned the number KNM-ER 1470, is dated at between 2.6 to 2.8 million years of age. Richard Leakey and Alan Walker, working together in the summer of 1984, discovered the complete skeleton of a twelve year old boy, estimated to have died between 1.6 and 1.55 million years ago, which they nicknamed Fossil Boy.

Although it has been suggested that Fossil Boy may be a *Homo erectus* specimen, it appears to have characteristics, such as a small brow ridge, more representative of *Homo habilis*. The skull of Fossil Boy has a bony socket in the skull which only humans, not apes, possess. This is called Broca's area, and it is the section of the brain which controls speech. Can one assert that the appearance of Broca's area and the capacity for speech mark the dividing line between primate and true man? If the answer is yes, then all species of *Australopithecus*, in which scientists have not yet found a Broca's area, must be considered as hominid but not human.

Homo habilis seems to have been similar to modern humans in physical structure, but it had longer legs and narrower hips than the average man, perhaps resembling in legs and hips the Masai warrior of today. *Homo habilis* also had a smaller skull than modern man, with a cranial capacity of about 800 cubic centimeters, as opposed to those of modern adult humans, whose cranial capacities vary between 1000 to 2000 cubic centimeters. The teeth of *Homo habilis* were similar, though larger than those of humans, and he had a receding jawline, or weak chin. Study the detailed, scaled drawing of a *Homo habilis* skull shown in figure one below.

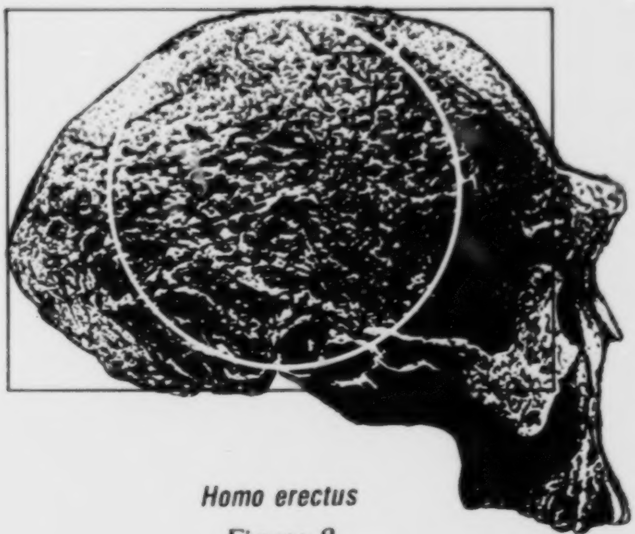


Homo habilis

Figure 1

Homo erectus

Many fossils have been found of the second species in the genus *Homo*, *Homo erectus*. Discovered in many parts of the world, *Homo erectus* was a heavier bodied, more massively constructed tool-user than *Homo habilis*. Early discoveries such as Peking Man and Java Man belong to the species *Homo erectus*. The oldest fossils have been dated between one and three quarters of a million years old. The cranial capacities for adult *Homo erectus* vary between 800 and 1400 cubic centimeters, which is smaller but similar to that of modern man. However, the bones and skulls of *Homo erectus* are heavier and more massive than those of modern man. Also, when viewed sideways, *Homo erectus* skulls are longer and flatter. From the front, the skulls have prominent brow ridges and low foreheads. Scientists have identified bulges in the brain area which might have controlled speech, but they have not yet located an actual Broca's area in *Homo erectus* (unless Fossil Boy is a *Homo erectus* specimen). Observe the detailed, scaled drawing of a *Homo erectus* skull in figure two.



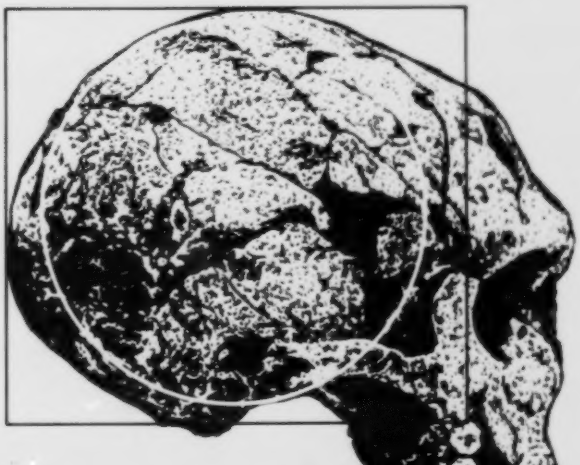
Homo erectus

Figure 2

Homo sapiens

The oldest fossils of *Homo sapiens*, our species, are dated at approximately one half million years. Some anthropologists believe that *Homo sapiens* are descended from *Homo habilis* and that *Homo erectus* represents an evolutionary dead end. Certainly the overall bone structure of *Homo habilis* more closely resembles that of modern man, although *Homo erectus* apparently possessed a greater brain capacity than the older *Homo habilis*. Also, *Homo erectus* spread over many parts of the world, whereas *Homo habilis* has only been found in Africa. Resolution of this issue, the antecedents of modern man, will require the discovery of many more specimens and much further study.

Varieties, or subspecies, of *Homo sapiens* include Neanderthal Man and Cro Magnon Man, as well as modern man. There is still great uncertainty about the disappearance of these early peoples and the emergency of modern man, or *Homo sapiens sapiens*, as we call ourselves. It is conceivable that descendants of Neanderthal and Cro Magnon Man still exist, but that they have been modified over the centuries. We humans, after all, do exhibit a great variety of shapes, sizes, and capabilities. Observe the detailed, scaled drawing of a *Homo sapiens neanderthal* skull in figure three below.



Homo sapiens neanderthal

Figure 3

You will now compare the three drawings shown in figures one, two, and three and measure their relative skull and brain capacity sizes.

NOTE: Students need a millimeter ruler to complete this exercise.

1. Determine the relative skull size by calculating the area of the rectangle which encompasses each skull. Remember that the area of a rectangle is determined by multiplying width times length. Record your findings in the figure four chart below.

2. Determine the relative brain capacity size by determining the area of the circle which lies inside each skull. Remember that the area of a circle is determined by measuring the diameter of the circle, dividing the diameter in half to determine the radius, and squaring the radius and multiplying it by the constant pi (π), or 3.14. Record your findings in the figure four chart below.

3. Determine the ratio of skull area to brain area. Record your findings in the figure four chart below.

Comparison of Skulls

	Skull Area	**Brain Area**	**Ratio**
Homo habilis			
Homo erectus			
Homo sapiens			

Figure 4

You should notice that as the skull area becomes more nearly rounded (as the enclosing rectangle becomes more nearly square), the more the brain area approaches the size of the skull area. By simple geometry, a round object contains more volume per unit of surface area than does any other shape. We do not know for a certainty how surface area to brain volume ratio reflects innate intelligence, but this ratio is the best correlation that anthropologists have devised for quantifying increasing intelligence. No one can convincingly correlate intelligence in modern humans to hat size, and yet such a measure is used by anthropologists to suggest increasing hominid intelligence during the course of evolution. Are they correct? Can you think of a better measure?

4. Assuming that figure one was ancestral to figure two, and two to three, what changes over time in brain area can be determined by your data in figure four?

5. Which of the three skulls shows the largest brain area and the smallest face area? Which shows the smallest brain area in comparison to the face area? Of what significance is this?

6. Aside from the skull measurements and comparisons you have made, what other fossil remains might be useful to anthropologists as they trace evolutionary sequences and relationships among specimens?

Many life forms display neoteny during the course of evolution. Neoteny means that descendants look like the juvenile forms of their ancestors.

7. How might you build a case for neoteny in man by studying the three skulls illustrated in this exercise? Explain.

Humans have a longer total gestational period than nearly all other animals. This period is defined as the time in which the fetus and the baby grow at a fast fetal rate. This period is twenty-one months in man. Both apes and humans have similar periods in the uterus, but an ape is born with a smaller brain weight when compared with a human baby, which at 400 grams weighs twice that of a baby ape. After birth, human babies continue to follow a fast fetal growth pattern for a year, whereas apes and most other animals shift to a slower growth rate upon birth.

8. How might human growth rate and neoteny be related? Explain.

Resources

Audio Visual Narrative Arts, Inc. *Ape, Man and Whale: Intelligence and Language.* #08383-910, 4 filmstrips and cassettes.

Center for Humanities. *Three Billion Years of Life: The Drama of Evolution.* #01008-910, 6 parts, slides and cassettes or video.

Walker, Alan. "Fossil Boy," *Johns Hopkins Magazine*, December 1985.

Weaver, Kenneth F. "The Search for Early Man," *National Geographic*, November 1985.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

Australopithecus
Broca's area
Cro Magnon
Homo erectus
Homo habilis
Homo sapiens
Neanderthal
neoteny
sagittal crest

Review

22. Fossil Boy

Name______________________________

Date______________________________

Matching (answers may be used more than once)

______ 1. In evolution, when the descendants look like the juveniles of their ancestors

______ 2. Possesses a sagittal crest

______ 3. Possesses a protruding brow ridge

______ 4. In the brain, the center for speech

______ 5. The oldest known man in the genus *Homo*

______ 6. A modern man

______ 7. Discovered and named by Louis Leakey in 1962

______ 8. Discovered by Alan Walker and Richard Leakey in 1984

______ 9. An archaic modern man

______ 10. Discovered by Richard Leakey in 1974

A. *Homo sapiens sapiens*

B. *Homo erectus*

C. *Homo habilis*

D. *Australopithecus*

E. neotony

F. Broca's area

G. Fossil Boy

H. Neanderthal

I. #1470

Essay

Explain the changes that have taken place over time in the evolution of man, as we understand it today.

23. Laboratory
Soil Communities

When you have completed this laboratory you should be able to:

1. Appreciate the importance of humus in soil.
2. Understand the role of organisms in recycling plant nutrients.
3. Collect, separate, and identify various organisms which exist in leaf litter and topsoil.

Soil Humus

Soils consist of two primary components. The inorganic components are mineral and range in size from gravel to clay. The organic components are called humus, and they constitute one to five percent by weight of an average soil type. Humus gives dark color, fertility, and friability to good soils. The organic components of humus are also the major source for such elements as phosphorus, sulfur, and nitrogen so important to new plant growth. Humus provides the main food source for soil microorganisms, and it contributes significantly to a soil's water-holding capacity.

Humus comes from both plants and animals. Animals such as centipedes, mites, and worms break down excretia and eat plant debris. Fungi and bacteria further break down organic materials into component parts. Eventually humus is broken down into its constituent compounds, but the supply of humus is constantly replenished through recycling.

The amount of humus accumulated in a soil depends on many factors, but two important ones are soil temperature and aeration. Organic matter accumulates in soils with poor aeration, since aerobically respiring organisms are limited in such soils. Also, the organic content increases with decreased temperatures, because the actions of microorganisms are reduced in colder climates. Moisture also is important in the decomposition of humus and the leaching out of soluble organic compounds. Therefore, tropical soils, because of high temperature and high rainfall, are very low in humus. The jungle's available supply of organic nutrients is stored chiefly in the jungle plant cover itself.

There are still other factors which influence the organic content of soils. The nature of the organic litter is important. For example, the needles of evergreens decompose very slowly in comparison to the leaves of deciduous trees (leafed trees such as maples and oaks). Soil pH also is important, as evidenced by earthworms which prefer soils which are not acidic.

Soil Organisms

As indicated above, organisms which live in litter and topsoil perform the essential role of reducing plant and animal debris to organic compounds which can be taken up as nutrients through the roots of new generations of plants. Soil organisms are dependent on their immediate environment. Abiotic factors such as rainfall, temperature, and soil type are important. Biotic factors, such as other organisms in the same physical environment, and how they interact and influence the life and reproductive ability of each other, are essential determinants of a soil community. There are many interactions among all the organisms in an environment which determine the concentrations of each species. These interspecific interactions, together with the physical environment, make up an ecosystem.

Ecosystems

An ecosystem consists of a group of organisms and the environmental factors which affect them. A community is any group of interacting organisms, plant and animal, within an ecosystem. Each community has a characteristic species composition and species density. It is a major task to define an ecosystem small enough to be able to actually determine all the plants and animals within the system, and yet also to have the system large enough to show the true interrelationships that are maintained within it.

Ecosystem structure may be determined by assaying (counting and identifying) each plant and animal. The assay can be direct, by actually counting all the organisms living within it, or indirect, by using sampling methods to count all the organisms within a small area, and multiplying that count to determine the count for the entire ecosystem.

A Soil Community

In this laboratory you will sample a small amount of leaf litter and topsoil, thereby indirectly determining what the plant and animal communities are for the area in which your sample was taken. You will collect any small animals present in your samples and categorize them as to type.

Pre-lab

Supplies needed:

Equipment

2 ring stands
2 support rings
3 250-ml. beakers
10 cm. rubber tubing
dissecting scope
eye dropper
small dishpan or bucket
light source
Berlese funnel
Baermann funnel
pinch clamp
microscope slide, or white tile plates
3 petri dishes

Materials

2 plastic bags, 1 liter size
2 plastic ties, or rubber bands
25 cm.^{2} cheesecloth or gauze
3 pieces filter paper
spade or small shovel
25 ml. 70% ethyl alcohol
100 g. salt

Special Preparations

1) If Berlese funnels are unavailable at your school, make an aluminum foil cone with paper clips attached to a deep kitchen sieve. Support this substitute on the support ring of a ring stand, just as you would a Berlese funnel. See the figure one illustration in this laboratory.

2) If Baermann funels are unavailable, make something similar by using a large glass or plastic funnel with a sieve or screen inserted. The soil sample in cheesecloth is to be placed on top of the sieve which has been inserted inside the funnel. Again, support this substitute on a support ring of a ring stand, just as you would the Baermann funnel. See the figure two illustration in this laboratory.

3) If the collection of leaf litter and topsoil is given as a homework assignment, students may provide their own bags and shovels. If the collection of leaf litter and topsoil is done as a class activity, allow one-half of a class period to complete, as students should collect samples from different areas around the school

4) If this laboratory is conducted during cold months, allow the soil and litter one week to slowly warm to room temperature before continuing. Slow warming allows organisms to survive as they recover from a winter's hibernation. A sudden change in temperature can produce shock death to organisms, and they will decay before being observed.

5) The filter paper should exactly fit the petri dishes.

Time Required

The soil communities laboratory requires one and a half hours of laboratory, as well as time outside the classroom for leaf litter and topsoil collection, in addition to preparations, discussion, and review.

Procedure: Pre-lab Outside Activity

Supplies needed: 2 1-liter plastic bags with ties and a small shovel or spade.

During this activity student groups will collect leaf litter and topsoil. They should avoid taking their samples from areas likely to have been sprayed for insect control, such as around a school lawn. Leaf litter and topsoil should be taken from the same undisturbed area so that organisms which can live in both litter and soil will be correctly represented.

Depending upon the neighborhood and the nature of the school grounds, students will perform this activity either at home or during part of the class period.

Put masking tape on one plastic bag, and label it with the term "leaf litter," your name or the name of your laboratory group, class, and date. Put masking tape on the other plastic bag, and label it with the term "soil," your name or the name of your laboratory group, class, and date.

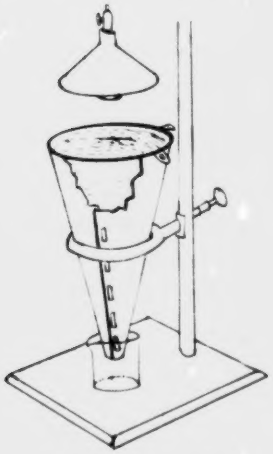
Find an area which has both leaf litter and humus in the topsoil. Use the spade to first half fill the bag labeled "leaf litter" with leaf litter. Then half fill the bag labeled "soil" with topsoil taken from directly under the area in which you collected the leaf litter. Tie both bags with plastic ties or rubber bands.

If your collecting is done when the soil is cold or frozen, the litter and soil must be allowed to come slowly to room temperature over the course of a week. **Do not immediately put cold soil or litter into a warm room, or you will kill many of the organisms.**

Procedure: Partial Hour 1

Supplies needed: 2 ring stands, 2 support rings, light source, Berlese funnel, Baermann funnel, 2 250-ml beakers, 10 cm. rubber tubing, pinch clamp, 2 plastic bags previously half filled with leaf litter and topsoil, 1 plastic tie or rubber band, 25 ml. 70% ethyl alcohol, and 25 cm.^{2} cheesecloth or gauze.

Steps

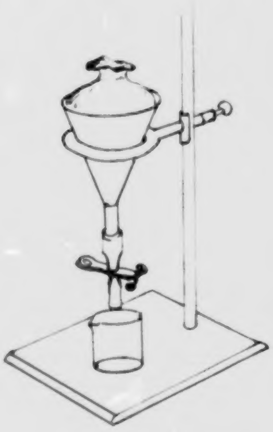


Berlese Funnel

Figure 1

A. Set up a Berlese funnel, as illustrated in figure one, left. Fill the sieve about half full of leaf litter, and fill the beaker about half full of 70% alcohol. The alcohol acts as a preservative for the insects leaving the leaf litter. Station the light surce so that it is at least 20 cm. away from the closest leaf litter. If it is too close or too hot, the litter will heat too quickly, and some of the animals will die before dropping into your collecting beaker. If this happens, your count will not be accurate. Label this set-up with your name, date, and class, and leave it for twenty-four to seventy-two hours.

B. Set up a Baermann funnel, as illustrated in figure two, right. Fill the cheesecloth with approximately half the topsoil collected, and tie it with a plastic tie or rubber band. Place the cheesecloth inside the funnel on the sieve. Close the pinch clamp and flood the funnel with water without allowing any water to overflow. Remove the pinch clamp for a moment to allow the rubber tubing to fill with water.



Baermann Funnel

Figure 2

and then replace it. Place the collecting beaker directly under the rubber tubing on the ring stand. Label this set-up with your name, date, and class, and leave it for twenty-four to seventy-two hours.

Procedure: Hour 2

Supplies needed: set-ups from partial hour one, dissecting scope, microscope slide or white tile plates, eye dropper, beaker, 3 petri dishes, small dishpan or bucket, 100 g. salt, and 3 pieces filter paper.

Steps

A. Berlese funnel set-up: count and identify the organisms which have fallen into the alcohol, using figures three and four to aid in your identifications. Use the eye dropper to place individual organisms on a microscope slide or tile plate for viewing with a dissecting scope.

1. List and draw all the types of organisms which have fallen into the alcohol from your Berlese funnel set-up in the space provided below. Also count how many of each kind fell into the alcohol-filled collecting beaker. Depending upon locality, you should have collected from three to ten different types.

Name of Organism	How Many	Drawing
1) ______________		
2) ______________		
3) ______________		
4) ______________		
5) ______________		
6) ______________		
7) ______________		

Name of Organism	How Many	Drawing
8)		
9)		
10)		

Common Leaf Litter Organisms

Phylum Arthropoda: Class Insecta
— one pair antennae, three pairs of legs as well as wings, and three body divisions
— may find adults, immatures (such as those of grasshoppers), and larvae; do not confuse these with true worms
— most common in leaf litter: springtails (collembola) and beetles

Phylum Arthropoda: Class Arachnida
— no antennae, four pairs of legs, and two body divisions
— most common: spiders and mites

Phylum Arthropoda: Class Crustacea
— two pairs of antennae
— most common: sowbugs (isopods)

Phylum Arthropoda: Class Diplopoda
— one pair of antennae, two pairs of legs per body segment, and two body divisions
— most common: millipedes

Phylum Arthropoda: Class Chilopoda
— one pair of antennae, one pair of legs per body segment, and two body divisions
— most common: centipedes

Phylum Annelida
— segmented worms
— most common: earthworms

Phylum Nematoda
— unsegmented worms, with round, slender, usually light-colored bodies
— most common: nematodes

Phylum Rotifera
— bodies have external cilia on a crown, which is disk-shaped
— only found occasionally.

Figure 3

Common Leaf Litter Organisms

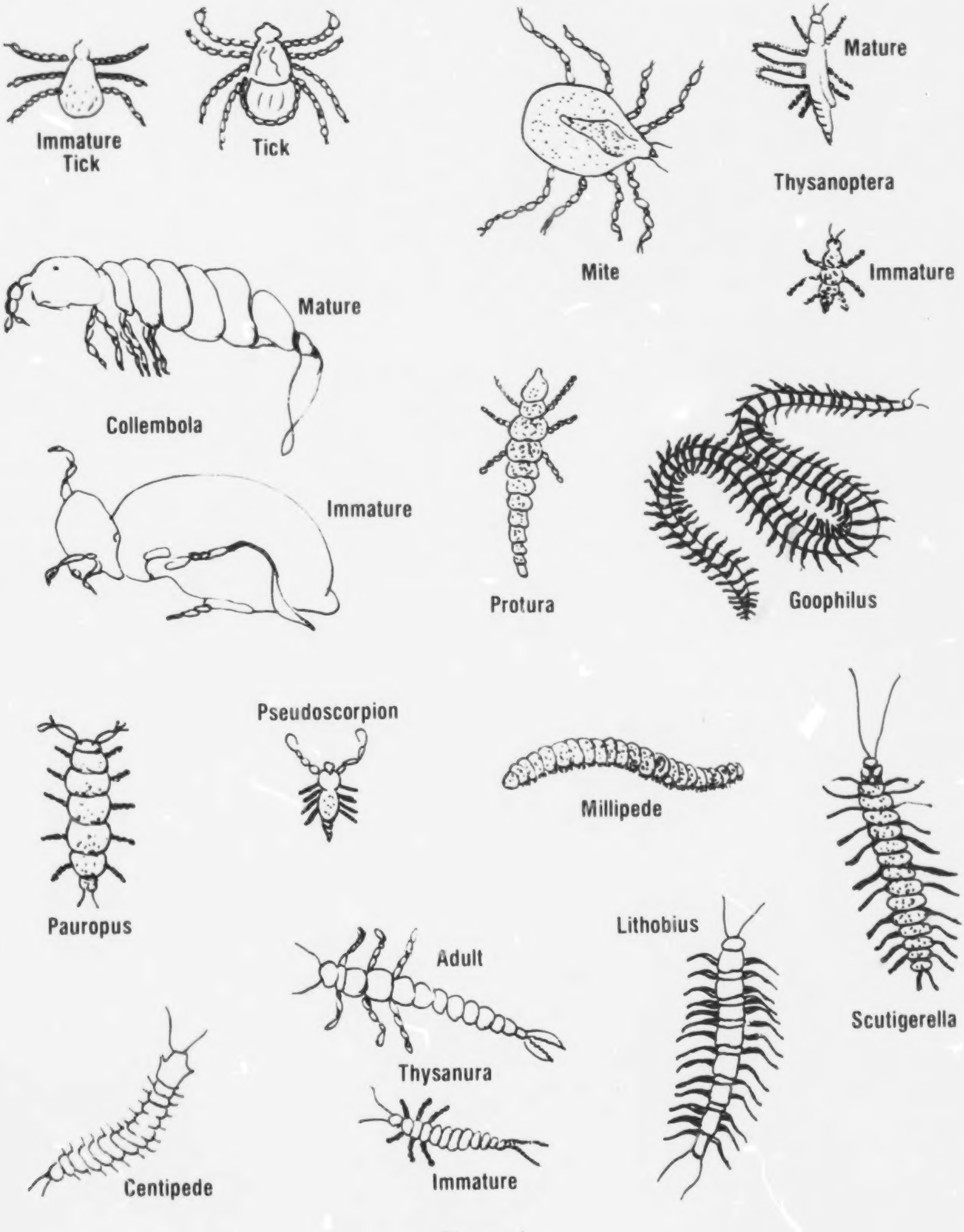

Immature Tick
Tick
Mite
Mature
Thysanoptera
Immature
Mature
Collembola
Immature
Protura
Goophilus
Pseudoscorpion
Pauropus
Millipede
Scutigerella
Lithobius
Adult
Thysanura
Immature
Centipede

Figure 4

NOTE: If students do not recall from their middle-school life sciences course such classification terms as phylum and class, as used in figure three above, they should now review these terms by reading the discussion portion of exercise twenty-five of this manual.

B. Open the pinch clamp on your Baermann funnel set-up, and allow the collected water to drain into the beaker below. Use figures three and four above to aid in your identification. Use the eye dropper to place individual organisms on a microscope slide or tile plate for viewing with a dissecting scope.

2. What do you observe in the water collected in the beaker? ____

____

____

3. List and draw all the organisms which have fallen into the collecting beaker from your Baermann funnel set-up in the space provided below. Also determine how many of each kind you collected.

Name of Organism	How Many	Drawing
1) ____________________		
2) ____________________		
3) ____________________		
4) ____________________		
5) ____________________		
6) ____________________		
7) ____________________		
8) ____________________		

Name of Organism	How Many	Drawing
9)		
10)		

4. Were there organisms present in the leaf litter not present in the soil sample? If the answer is yes, how many types were present in the leaf litter but not in the soil? Name them.

5. Why do you think some organisms could be found only in leaf litter or only in soil?

6. Why do you think some specimens could be found in both leaf litter and soil?

C. Fill a small dishpan or bucket to within five centimeters of the top with water. Add approximately 100 g. salt to the water and stir until it has dissolved.

You are now ready to look for small soil organisms using the Tullgren method for arthropod extraction, as detailed in step D. The Tullgren method is useful for observing organisms which are capable of easy movement through loose soil or litter material.

D. Take the remaining soil sample and make sure it is friable by **gently** rolling the soil until it is loose and in small particles. Do not be too vigorous because you might destroy some of the tiny organisms in the soil. Stir the water in your pan vigorously while you slowly pour the soil into the water. Some of the material in the soil will float to the surface of the water, although this may not be visible immediately in your by now very muddy appearing pan. Skim off the surface water into a beaker to collect the floating material.

E. Place a piece of filter paper in a petri dish. Pour 2 to 3 mm. of the skimmed water over the bottom. Repeat this procedure, using two additional petri dishes and filter paper.

F. Study these dishes under a dissecting scope. Try not to disturb the water in any way while looking for organisms. They are small, but they will reveal their presence by moving.

7. List and draw all the organisms you observe in the space provided below. Use figures three and four above to assist with identifications. Also determine how many of each kind you collected.

Name of Organism	How Many	Drawing
1) ____________________		
2) ____________________		
3) ____________________		
4) ____________________		
5) ____________________		
6) ____________________		
7) ____________________		
8) ____________________		
9) ____________________		
10) ____________________		

8. Did you find any soil organisms by the Tullgren method which were not found by the Baermann funnel? If so, how do you account for this difference?

9 Which phylum or class was most commonly represented in your three samples?

10. Why was that phylum or class dominant in your particular ecosystem? Consider season, moisture and humus levels, local plant communities, location from which sample taken, etc.

Resources

Center for Humanities. *Ecology · Sampling Methods and Field Techniques.* #01018-910, video.

Prentice-Hall Media. *Ecology: Interactions and Environments.* Two units consisting of 7 filmstrips and cassettes, #31419-910 and #31420-910.

Prentice-Hall Media. *The Case of the Bighorn Sheep: an Ecological Mystery Story.* #08990-910, 2 filmstrips and cassettes.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

abiotic
biotic
ecosystem
humus

Review

23. Soil Communities

Name______________________________

Date_______________________________

Multiple choice

______ 1. A group of plants and animals living together in a given area is considered to be a(n)
a. ecosystem
b. biome
c. population
d. community

______ 2. Decayed leaves, roots, and other organic matter in topsoil is
a. subsoil
b. peat
c. humus
d. soil flora

______ 3. Soil organisms
a. are not necessary in the food chain
b. return energy which is lost to the food chain
c. can replace the photosynthetic activities of green plants
d. return materials to the food chain

______ 4. An important factor in any ecological succession is that as various types of plants grow and die
a. they add humus to the soil
b. plants never mutate
c. animals remain the same
d. the environment does not change

______ 5. Populations of organisms within a community are prevented from increasing too rapidly and becoming too large by
a. biological controls
b. physical controls
c. interactions between organisms
d. all of the above

______ 6. Why are tropical soils very fertile?
a. vegetation is abundant and decomposes rapidly
b. rainfall is taken up by plant roots before it can penetrate far enough to leach minerals out of the soil
c. microorganisms work more efficiently in warm temperatures
d. they are not very fertile

______ 7. Which of the following statements about humus is not true?
a. it is formed by the decomposition of clay
b. it adds nutrients to the soil
c. it modifies the consistency of soil
d. it is the result of the breakdown of organic debris

______ 8. An element which is very important to new plant growth is
a. aluminum
b. iron
c. magnesium
d. nitrogen

______ 9. The ecological unit composed of organisms plus their physical environment is the

a. niche
b. population
c. ecosystem
d. succession

______ 10. Desert soils are potentially very fertile because

a. microorganisms work very efficiently in the hot desert environment
b. there are many plants in the desert which contribute to the build-up of humus
c. few minerals are leached from the soil due to low rainfall
d. they are not potentially very fertile

24. Class Laboratory

Bacterial Population

When you have completed this laboratory you should be able to:

1. Culture bacteria present in the environment.
2. Observe a pattern of epidemic spread in a human population.
3. Consider environmental effects upon the culturing of bacteria colonies.

Bacteria

Bacteria are prokaryotic organisms which, under favorable conditions, reproduce by simple fission about three times every hour. When there is insufficient water, oxygen, warmth, or food, bacteria cover themselves with a hardened, protective wall called a spore case. They remain in this inactive state until conditions are again favorable to growth. Because bacteria are small and light, they are easily airborne and spread.

The small size of bacteria makes it nearly impossible to study them individually. They are grown in large colonies, or cultured, before study in the laboratory. Unlike higher organisms which are classified on the basis of structure, single-celled bacteria initially are classified by shape. All bacteria are shaped like balls (cocci), rods (bacilli), or spirals (spirilla).

Bacteria also often are further classified by their planes of division as they undergo fission. For example, if cocci divide along one plane only, they tend to stick together like the pearls of a necklace. In this case they probably belong to the class *Streptococcus*, members of which can cause a sore throat. If cocci divide in any plane, thus forming irregular clumps of cells like a bunch of grapes, they probably belong to the class *Staphylococcus*, members of which can cause skin infections. Distinguishing bacterial species one from the other requires specialized knowledge.

Bacteria may be either helpful or harmful to humans and other organisms. You studied in station laboratory eleven how man uses some helpful bacteria. Harmful bacteria, on the other hand, are of great concern to medical doctors who try either to prevent or to treat bacterial infections. Preventive measures include the use of sterile instruments and materials when treating patients. Since bacteria are present literally everywhere, filtering devices are used in the ventilation systems of hospital operating rooms, nurseries, and food processing plants in an attempt to limit contamination by airborne bacteria.

Humans fight bacterial infections in various ways, such as using antibiotics to destroy bacterial cell walls. Since bacteria have cell walls, just as do eukaryotic plant cells, whereas animal cells have only cell membranes, an antibiotic attacks bacterial cell walls but does not harm a patient's cell membranes. The best cure, however, is not to get sick in the first place. This means maintaining good physical condition and living in sanitary conditions, since bacteria are present everywhere and always ready to begin high-speed fissioning whenever conditions permit.

Culturing Bacteria on Agar

Discovery of bacteria in the nineteenth century led to a search for ways in which to grow them so they could be studied in the laboratory. The first successful bacteria culturing technique was to grow them on the cut surface of potatoes. By the turn of the century the German biologist Robert Koch had devised a method still used today of growing bacteria on a special plate covered with materials on which bacteria can grow. The plate itself was devised by a French assistant to Robert Koch, and the plate, the petri plate, is named in his honor.

Robert Koch devised the use of agar as a culturing medium for bacteria growing on petri plates and in test tubes. Agar is an extract of seaweed which does not melt until it reaches a temperature of 100° C. Once it is liquefied, it does not solidify again until it is cooled below 42° C. Liquid agar can be mixed with a nutrient broth, poured into a container, and cooled to a temperature where the food enriched agar gels. Such a prepared medium is then ready for inoculation with bacteria.

In this laboratory you will culture bacteria present in the air, as well as study a bacterial species not harmful to man. After culturing airborne bacteria, you will determine how many types have been floating past your nose. You also will participate in the deliberate spread of a non-pathogenic bacterium among the class members and study the pattern of infection.

This laboratory is a whole class laboratory. Instead of working in laboratory groups, you will individually follow all steps as outlined below. The class as a whole will then pool results in order to obtain the data needed to draw meaningful conclusions.

Pre-lab

Supplies needed per individual student:

Equipment

grease pencil
access to refrigerator
access to incubator

Materials

5 sterile agar petri plates
1 petri plate with gumdrop
2 sterile cotton swabs
access to soap and water

Special Preparations

1) Sterile agar petri plates: add 20 g. peptone, 6 g. beef extract, 5 g. salt (NaCl), and 30 g. agar to 1 liter warm water. Slowly stir and bring to a boil. When the mixture appears clear and completely dissolved, autoclave or pressure cook it for 15 minutes at 15 pounds pressure to sterilize. When the agar mixture has cooled below 50° C., but is still liquid, pour the mixture into each petri plate to a depth of about one centimeter, using sterile procedure. Cover.

It is more convenient, but more expensive, to use sterile, disposable plastic petri plates which can be discarded at the conclusion of the laboratory. However, glass petri plates are reusable. If glass is used, it is best to autoclave the petri plates after filling with agar to assure that the plates do not contaminate the medium. Autoclave at 15 pounds pressure for 15 minutes.

Allow the agar mixture to solidify in the covered plates at room temperature and then store in a refrigerator, upside down, until needed for the laboratory. The agar plates may be prepared up to two weeks in advance of the laboratory, if they are properly stored and refrigerated to protect against contamination.

2) Prepare one gumdrop petri plate per student. Do this by putting one piece of gumdrop candy in a clean petri plate. Other types of candy may be used, but gumdrops have a convenient size and texture. Wet each gumdrop with a small amount of water on the day of the laboratory.

Purchase one tube of the bacterium *Serratia marcescens* from any biological supply house. The tube may be stored in the refrigerator if purchased well in advance of the laboratory. Incubate the tube several days before use.

Inoculate only one gumdrop per biology class with *Serratia marcescens*. The instructor should identify this dish in such a way that the students in the class will not know which dish contains the infected gumdrop. The instructor thus will know the source of infection but the students will act in the blind.

Time Required

The bacterial populations laboratory requires one and a half hours of laboratory, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Obtain all listed supplies. **Do not remove the cover of any petri plate until told to do so by your instructor.** Before starting the experiment, thoroughly wash your hands with soap and water. Label the cover of your five agar petri plates with your name and today's date. Do not write too large because other labels will be written on the covers.

B. Expose two petri plates to the air in your classroom by removing their covers for one minute. Replace the covers after one minute, and label these two plates "air" by writing on the cover with a grease pencil. Additionally label one of these "air" plates as "refrigerator" and the other as "incubator". Set these two plates aside.

C. Take the remaining three plates and, keeping them covered, turn them upside down. Using a grease pencil, draw a line across the bottom to divide it into two sections. Write the number one on the bottom of one section of each of the three petri plates and the number two on the other section of each plate. Turn the plates right side up again. The agar is semi-transparent, and you should be able to see the lines and numbers when looking through the top.

D. Label the cover of one of the three plates with the word "hand." Label the cover of the other two petri plates with the word "epidemic." Also label one of these "epidemic" plates with the word "refrigerator" and the other with the word "incubator."

E. Take the plate labeled "hand," and expose the number one section of the plate by touching the agar with your finger. Immediately replace the cover. Handle your gumdrop in order to make one of your hands as **sticky** as possible. Expose the number two section of the plate by touching it with your now sticky finger. Immediately replace the cover. **Do not wipe or wash your hand. You may be the source of infection.**

One of the gumdrops in the class has been contaminated with the bacterium *Serratia marcescens*, which is **harmless** to man. *Serratia marcescens* grows in an easy-to-see, bright red colony on agar plates.

You now will use your sticky hand to shake hands with the other members of your class, in a sequence specified by your instructor. As a class, you will trace the epidemic-like transmission of *Serratia marcescens* from the hand of the one class member with a contaminated gumdrop.

F. Under the instructor's supervision, each person by turns will shake hands with one other person selected at random from the class. Hand shaking contacts will be recorded by the instructor, and each person will get a turn at choosing a handshaking partner.

When it is your turn, you may choose any person in the class as a handshaking partner, even if that person has already shaken hands with someone else. Your instructor will record all contacts between individuals as they occur, so that the exact sequence of contacts will be know when the class tries to identify the source of infection and the course of its spread through the class.

G. Swab your sticky hand with a sterile swab, and then touch the number one section of agar in each of the two plates labeled "epidemic." **Immediately** replace the cover of each petri plate after touching with the swab. **Do not clean your sticky hand.**

H. Repeat the handshaking procedure. Again the instructor will specify handshaking sequence and record contacts as they occur.

I. Again swab your sticky hand with a sterile swab, and then touch the number two section of agar in each of the two plates labeled "epidemic." **Immediately** replace the cover of each petri plate after exposure. **Now wash your hands.**

J. Put the two plates labeled "refrigerator" upside down into a refrigerator. Put the other three plates, also turned upside down, into an incubator. Leave the plates to incubate for forty-eight to seventy-two hours.

1. In figure one below, copy the instructor's record of who shook hands with whom, and in what sequence, both through the first round of handshaking and the second round.

Hand Shaker	Round One		Round Two	
	Name	Shook Hands With	Name	Shook Hands With
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
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Figure 1

2. From the information gathered in question one, predict the number of individuals in both rounds one and two whose petri plates will be contaminated with *Serratia marcescens*.

Procedure: Partial Hour 2

Students need their petri plates from hour one of this laboratory.

Steps

A. Retrieve your five petri plates from the refrigerator and incubator. **Do not open them. They may have become contaminated with a potential pathogen.** Study them with the cover in place for any signs of growth.

3. How many colonies of bacteria are growing on the petri plate labeled "air" and "refrigerator"? How many different **types** of colonies are there?

4. How many colonies of bacteria are growing on the petri plate labeled "air" and "incubator"? How many different **types** of colonies are there?

5. Are the types of bacterial colonies growing on the two "air" plates similar? Are there any bacterial colonies growing on one of the plates and not on the other? Why or why not?

6. Which environment, the refrigerator or the incubator, seems to be the best for growing bacteria?

7. Are there more or fewer bacterial colonies growing on the plate labeled "hand" than on the plates labeled air? Why is this the case?

8. Is *Serratia marcescens* growing on your "hand" plate? What does this mean?

(If yes, do not reveal this to anyone until directed to do so.)

9. Study the two plates labeled "epidemic." How many colonies of bacteria are growing on both sections of the petri plate labeled "refrigerator"? How many different **types** of colonies are there?

10. How many colonies of bacteria are growing on both sections of the petri plate labeled "incubator"? How many different **types** of colonies are there?

11. Are the types of bacterial colonies growing on the two "epidemic" plates similar? Are there any bacterial colonies growing on one of the plates and not on the other? Why or why not?

12. Were you at any time infected with *Serratia mercescens?* If so, when? ______

B. The instructor will now read the name of each student. Students are to announce to the class whether or not they had positive readings for *Serratia mercescens* on the "epidemic, incubator" plate during either round one or round two, or both.

13. As each student announces their results, the others are to mark on the chart in figure one those students with positive readings from either round.

14. From the data recorded in figure one, determine who the culprit responsible for the *Serratia marcescens* epidemic is, and write the name in the space provided.

There should have been only one student with a positive reading on the "hand" plate, the one with the inoculated gumdrop, since *Serratia marcescens* is not normally present in the environment. This student is now to reveal their identity. The others may wish to reflect upon their skills as detectives.

15. Trace the course of the spread of *Serratia marcescens* through the class. Do you think that this is the way most epidemics spread? Why or why not?

16. What are other ways that populations of organisms can be spread throughout an environment? ______

Resources

Center for Humanities. *Ecology: Populations, Communities and Biomes.* #010630910, either 4 slide programs with cassettes, or one 4 part video presentation.

Human Relations Media. *Bacteria: Invisible Friends and Foes.* #772-00-CSGQ, 3 filmstrips and cassettes.

Human Relations Media. *The Body Against Disease.* #730-00-CSGQ, 3 filmstrips and cassettes.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

agar
bacillus
coccus
epidemic
Koch, Robert
spirillum
Staphylococcus
Streptococcus

Review

24. Bacterial Populations

Name______________________________

Date_______________________________

Fill in the blanks

1. The structure found in a bacterial cell but not in an animal cell is the ________________________
2. There are three basic bacterial shapes: coccus, spirillum, and ______________________________
3. The type of reproduction in which a bacterial cell splits, forming two identical cells is known as ____
4. Sore throats are caused by ____
5. A ____ is capable of producing disease.
6. Bacteria have ____ just like eukaryotic plant cells.
7. Bacterial disease may be transmitted by ____
8. A severe outbreak of a disease is known as an ____
9. ____ named the petri plate after one of his assistants.
10. He also developed the use of __________________________ as a medium upon which to culture bacteria.

25. Exercise

Classification

When you have completed this exercise you should be able to:

1. Understand the organization of dichotomous keys.
2. Use a dichotomous key to identify seventeen insects.
3. Construct a dichotomous key for ten imaginary creatures.

Biological Classification

Biological classification, called taxonomy, is the study of the relationships and differences between plants and animals. Classification systems are used to identify and place individual species. The processes of classification involve a sequence of separating a group of organisms into subgroups and then into further subgroupings until a particular species can be isolated from closely related species. The terminology of biological classification is based upon Latin. It is a universal technical language, used by every biologist of every country in the world.

It is useful to be able to communicate with others accurately. To use a personal example from the author's childhood, one day my mother said to my father, "Bill, there's something moving in the bushes. Would you go see what it is?" My father went outside and walked toward the bushes. Suddenly my mother started yelling, "Stop, Bill, it's a polecat." As my father kept walking toward the bushes, mumbling "What is a polecat?", he was sprayed by an evil smelling fluid. Even though my father speaks American English, he did not grow up in the same region as my mother, where polecat is the word for a skunk. If my mother had used a more universal term, both a heated argument and an awful smell could have been avoided. Any biologist from Russia, China, or Nigeria would have recognized the genus term for skunk, *Mephitis*. It is by the use of such technical terms that the world's scientists communicate with each other.

Dichotomous Keys

Dichotomous, or two-part, keys operate on the same principle as computers. A series of yes/no or either/or statements takes you through a set of statements about the structure of an organism. These sets of opposing statements, A or B, must be answered correctly at every step in the process, thus requiring careful study. Having answered a series of questions about an organism's structure, you arrive at the correct identification. This identification most typically is given by genus and species. For example, in exercise twenty-four you learned that *Homo* is the genus name for man, *sapiens* is the species name for human, and *sapiens* used again is the name for the particular race of man alive today. We, as you recall, are classified as *Homo sapiens sapiens*.

Full taxonomic placement, however, requires identification of the organism by kingdom, phylum, class, order, family, genus, species, and variety or race. This sequence goes from the most general, such as plant and animal kingdoms, to the most specific, such as the difference between a guernsey or holstein milk cow.

In this exercise you will identify seventeen insects as to their family, by using a dichotomous key. You then will construct your own key to identify ten imaginary creatures.

1. Study the insects illustrated in figure two, and identify them using the dichotomous key and family names given in figure one. Write names of the insects on the lines provided in figure two near each insect.

Insect Key

1A. Insect with wings .... go to **2**
1B. Insect without wings .... go to **10**

2A. Insect with two pairs of wings .... go to **3**
2B. Insect with one pair of wings .... go to **7**

3A. Insect with transparent wings .... go to **4**
3B. Insect without transparent wings .... go to **5**

4A. Insect with feathered appendages and broad abdomen .... **Cicadae**
4B. Insect with long, thin body .... **Chrysopidae**

5A. Insect with feathered antennae .... **Saturnidae**
5B. Insect without feathered antennae .... go to **6**

6A. Insect with feathered appendages .... **Aegeriidae**
6B. Insect with knobs on the end of the antennae .... **Nymphalidae**

7A. Insect with transparent wings .... go to **8**
7B. Insect without transparent wings .... **Corydalidae**

8A. Wings held vertically over the body .... **Simuliidae**
8B. Wings not held vertically over the body .... go to **9**

9A. Insect with long appendages and body .... **Tipuloidea**
9B. Insect with acutely angeled eyes and short antennae .... **Tabanidae**

10A. Insect is worm-like .... go to **11**
10B. Insect is not worm-like .... go to **12**

11A. Worm-like insect with a vertical tail .... **Syrphidae**
11B. Worm-like insect with obvious segments .... **Saturnidae**

12A. Antennae present .... go to **14**
12B. Antennae absent .... go to **13**

13A. Body slender, with thin long appendages .... **Ploiariidae**
13B. Body large, flat, with sharp hooked front legs .... **Belostomatidae**

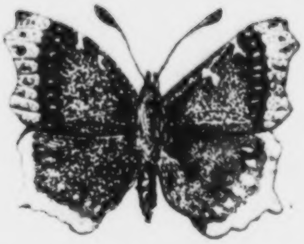
14A. Insect with highly feathered antennae and appendages .... **Ephemeridae**
14B. Insect without feathered antennae .... go to **15**

15A. Insect with long antennae trailing backwards along body .... **Blattariae**
15B. Insect without long trailing antennae .... go to **16**

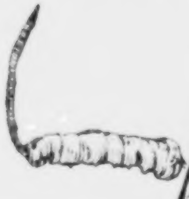
16A. Body soft, with abdomen divided into segments .... **Phthiriidae**
16B. Abdomen not divided into segments .... **Dytiscidae**

Figure 1

Insects for Identification



1) ______________________



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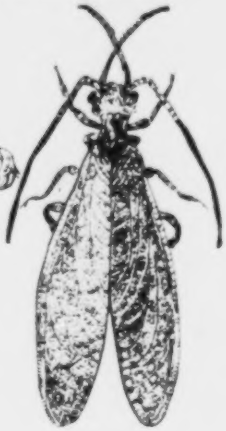

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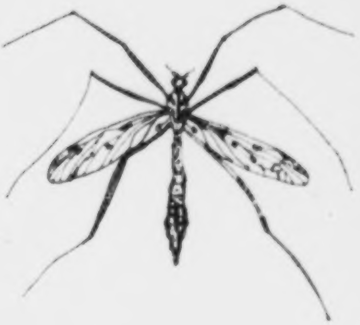
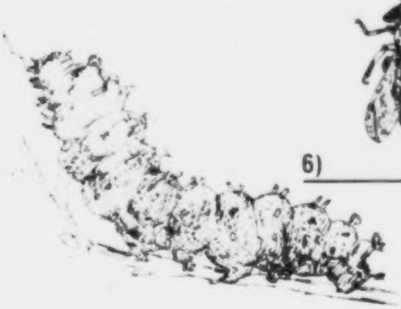


4) ______________________



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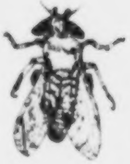

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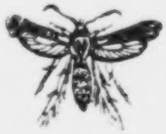

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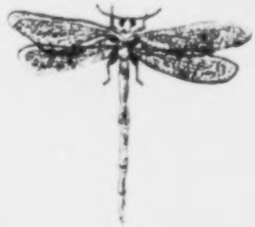
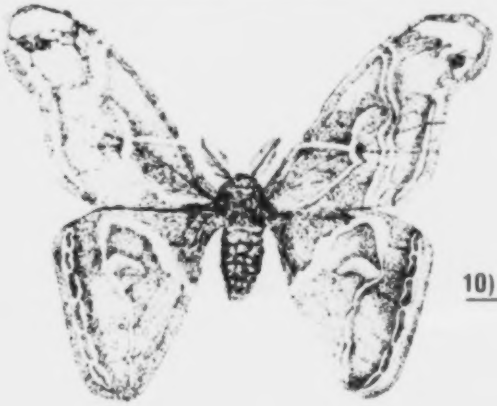
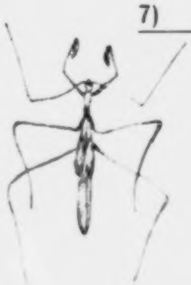


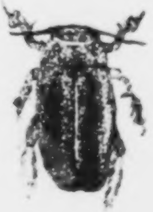
8) ______________________



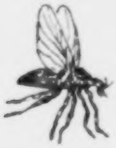
9) ______________________



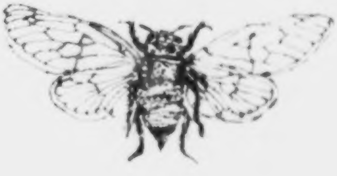
10) ______________________



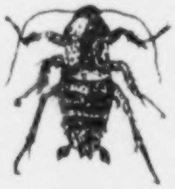
11) ______________________



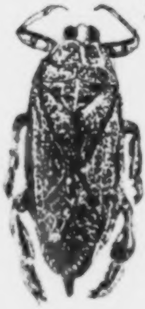
12) ______________________



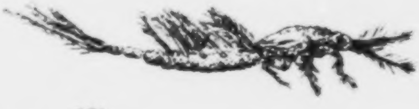
13) ______________________



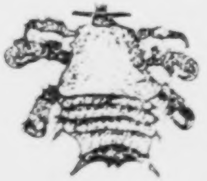
14) ______________________



15) ______________________



16) ______________________



17) ______________________

Figure 2

Listed below, along the left margin, are family names of the insects you keyed out. Also given are genus and species names, as well as common or familiar names and miscellaneous information. Genus and species names, however, are not given if the insect illustrated in figure two is simply a composite drawing representative of the entire family.

Aegeriidae — illustrated is *Canopia exitiosa*, the adult form of a peach tree borer.

Belostomatidae — illustrated is *Benacus griseus*, commonly known as a giant water bug.

Blattariae — illustrated is *Blatta orientalis*, commonly known as an oriental cockroach. Have you seen one before?

Chrysopidae — aphis lion.

Cicadae — illustrated is the adult form of the seventeen year locust, *Magicada septendecim*.

Corydalidae — illustrated is the adult form of *Corydalis cornuta*, commonly known as a dobson fly. The larval form of this insect is widely used by fishermen as bait for bass.

Dytiscidae — diving beetles.

Ephemeridae — illustrated is the nymph form of *Ephemera*, commonly known as a mayfly. Some of the feathered appendages are actually gills.

Nymphalidae — illustrated is *Aglais antiopa*, commonly known as the mourning cloak butterfly.

Phthiriidae — illustrated is the human body louse, *Phthirius pubis*. Now you know what they look like.

Ploiariidae — thread legged bugs.

Saturnidae — giant silk worm moths. Both the adult form of *Philosamia walkeri*, commonly known as the Asiatic silk worm moth, and the larval form of another moth, *Samia cecropia*, commonly known as the luna moth, are illustrated.

Simuliidae — known colloquially as a black fly, turkey gnat, or buffalo gnat. It is a biting insect of North America.

Syrphidae — illustrated is the larval form of *Eristalia tenax*, commonly known as the rat-tailed maggot. The "tail" lengthens or shortens depending on how deeply the maggot goes into the foul water or fluid of the decaying carcasses in which it lives. The maggot breathes through the tail-like appendage. The adults are flies which look like bees and are called drone flies.

Tabanidae — horsefly. Only the females bite.

Tipuloidea — daddy long legs.

Imaginary Creatures

Now study the imaginary creatures illustrated in figure three.

2. Name the ten creatures, using any descriptive genus and species terms you wish. Write the names in the spaces provided below.

1) ______________________________

2) ______________________________

3) ______________________________

4) ______________________________

5) ______________________________

6) ______________________________

7) ______________________________

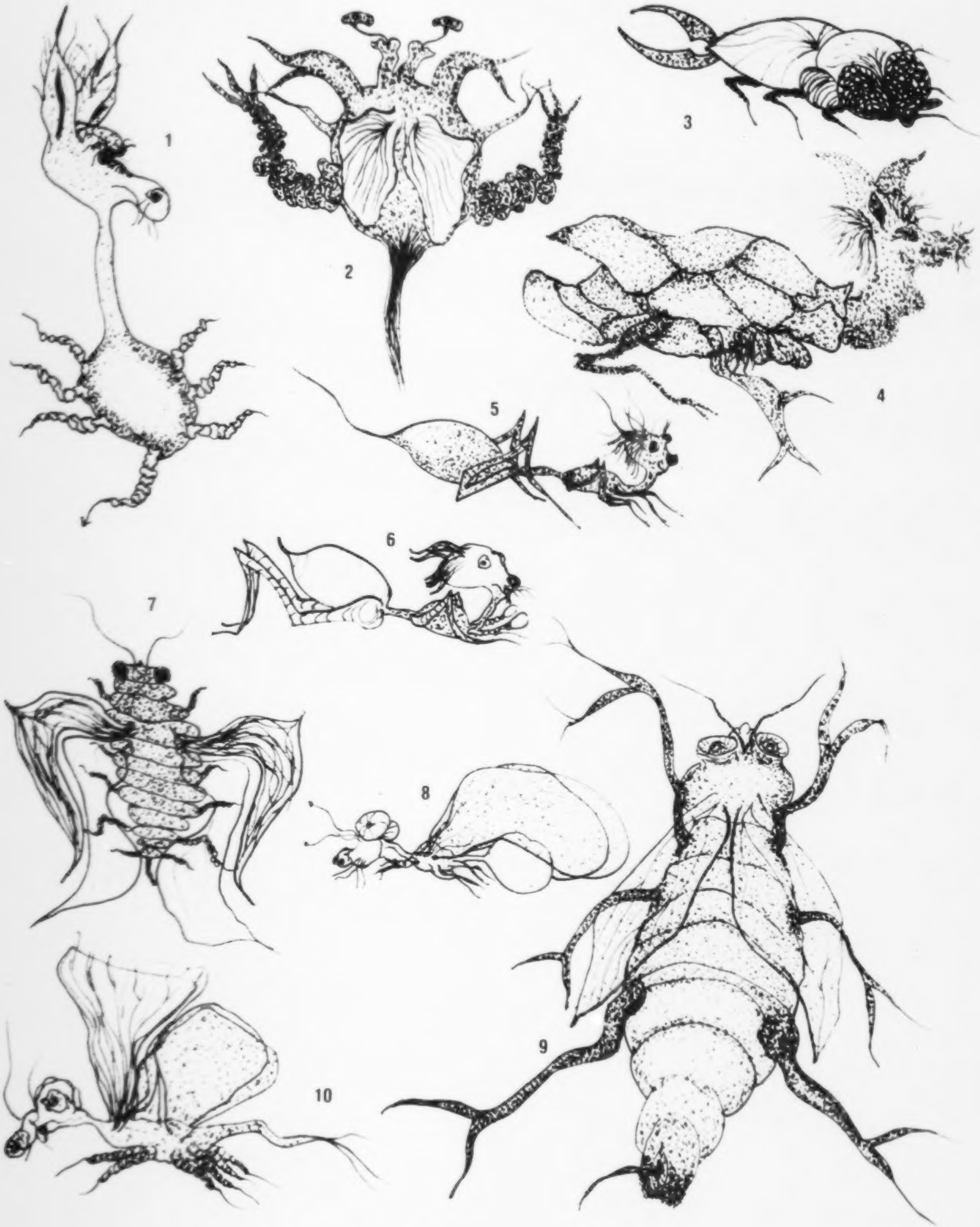
8) ______________________________

9) ______________________________

10) ______________________________

By custom, the honor of naming a newly discovered organism is granted to the naturalist who first isolates and describes a previously unknown species.

Imaginary Creatures


1
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6
7
8
9
10

Figure 3

3. Construct, in the space provided below, a dichotomous key for the ten imaginary creatures illustrated in figure three.

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4. Is it possible to start your key with different structural questions than those you began with? What other features might you have used?

5. What features could you use to build a dichotomous key for classifying different types of automobiles?

6. How does a dichotomous key allow you to sort out an object more accurately than if someone just describes the object to you?

Resources

Center for Humanities. *Taxonomy: How Living Organisms Differ.* #01031-910, 4 parts, slides and cassettes, or video.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

dichotomous key

taxonomy

Review

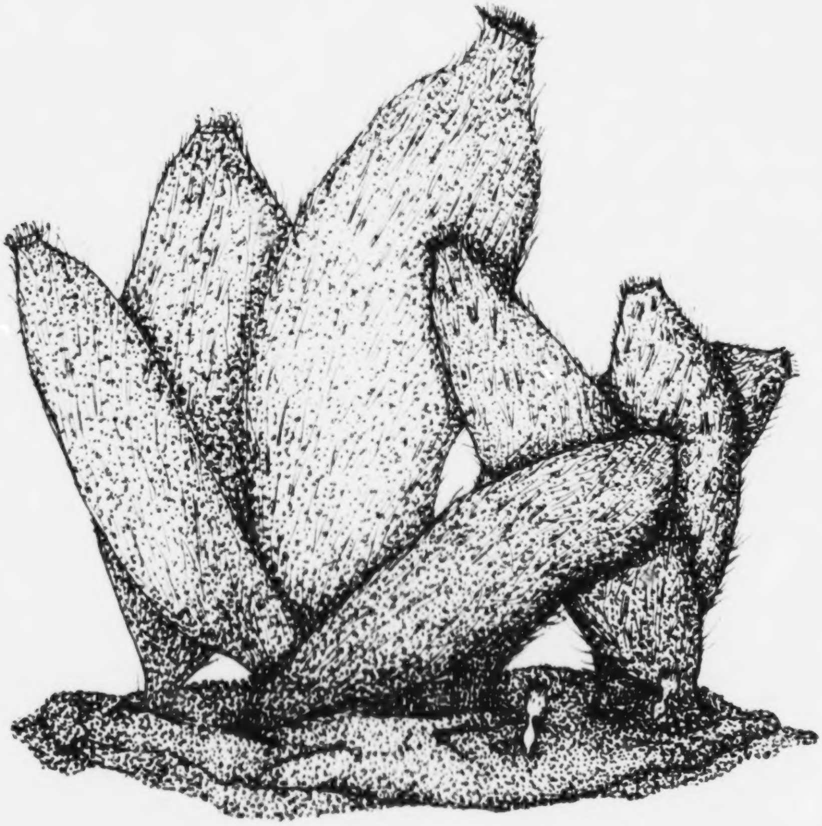
25. Classification

Name______________________________

Date_______________________________

In the space provided below, construct a dichotomous key to classify the following mammals: cat, horse, cow, dog, lion, tiger, deer, donkey, pig, bear, sheep, and giraffe.

Invertebrates



26. Laboratory

Protozoa

When you have completed this laboratory you should be able to:

1. Identify the four protozoan phyla.
2. Identify *Amoeba*, *Paramecium*, and *Euglena*.
3. Identify protozoan structures and understand their functions.

Phylum *Protozoa*

Animals that conduct all life activities in a single eukaryotic cell are classed as *protozoa*. (The term protozoa, incidentally, is used both as a technical and as a common term, as is done with a number of other phyla to be studied in succeeding laboratories). The phylum *protozoa* includes more than 50,000 different species. They live wherever there is water, be it fresh, salt, foul, or a soil particle film. Many are parasites living in another's body fluids. Man alone is host to more than twenty-five different pathogenic protozoa.

All protozoa are unicellular, but that one cell is a complex structure which conducts all life processes. Protozoan cell organelles perform the same functions performed by the organ systems of multicellular organisms. These organelles enable the protozoa to move, eat, digest, eliminate wastes, and reproduce.

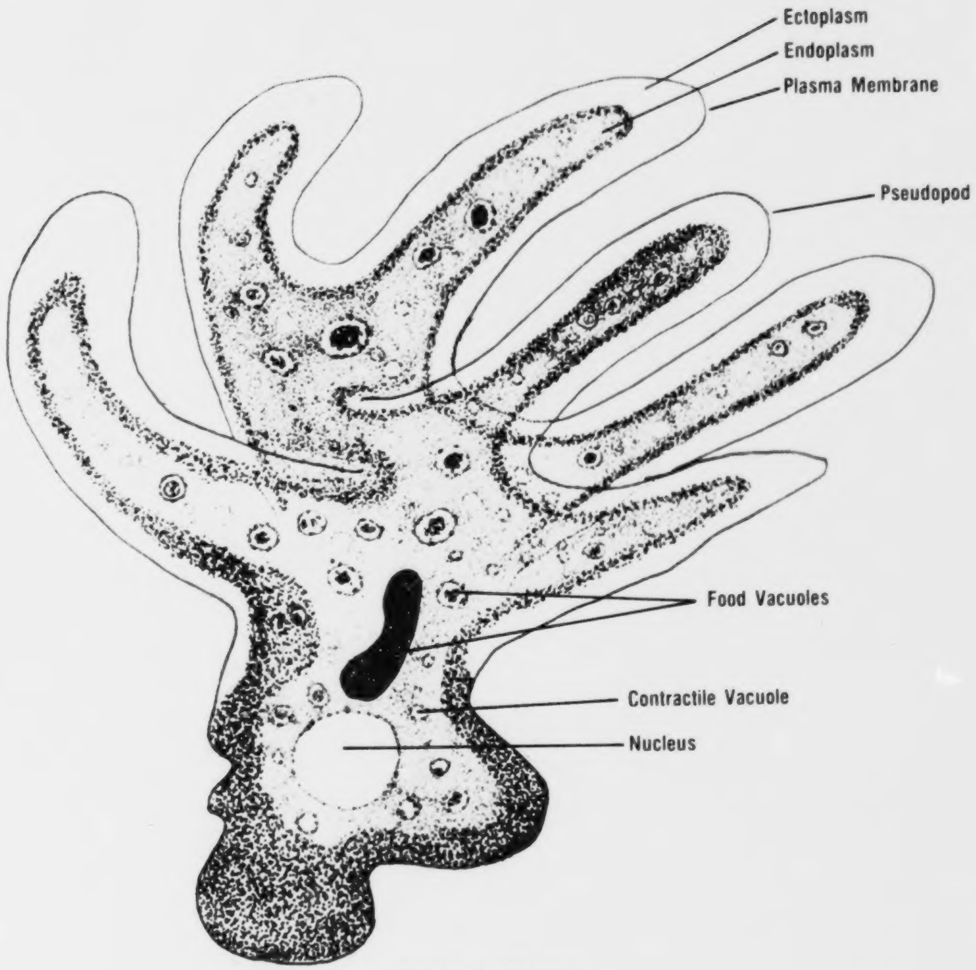
Protozoa are divided into classes according to the kind of cell organelles they use for movement. These four classes are as follows.

Sarcodina

A comparatively simple group of protozoa comprise the protozoan class *Sarcodina*. They are commonly known as the amoebae. The *Sarcodina* move by means of pseudopodia, or "false feet." Although *Sarcodina* can cause disease in man, ranging from a disease of the gums, gingivitis, to amoebic dysentery, the greatest number of *Sarcodina* are non-parasitic (technically termed "free-living"). While the majority of protozoa lack permanent skeletal structures, there are at least two large groups in the *Sarcodina*, the forminifera and the radiolaria, which possess conspicuous shells or skeletal structures. These two groups are found as fossils.

Free-living, fresh water *Sarcodina* live on the bottom ooze of ponds or slow streams, on the slimy coating of plant material in water, and in the surface scum. All *Sarcodina* reproduce by simple binary fission. Sometime in the distant past they lost the ability to genetically change or evolve to meet new environmental conditions. They appear today as they did millions of years ago.

The best known *Sarcodina* to biology students is *Amoeba proteus*. It exhibits traits characteristic of the class. *Amoeba proteus* commonly is studied because of its large size and high activity levels. Study figure one, and note the relative size, shape, and location of its organelles.



Amoeba Proteus

Figure 1

Sporozoa

All *Sporozoa* are parasitic. They have no obvious means of locomotion and produce spores toward the end of their life cycle. The majority attack invertebrate organisms, such as earthworms and cockroaches, but some cause disease in man. They exhibit a complicated life cycle involving two hosts, reproducing both asexually by fission and sexually by sporozoite formation.

A malarial protozoa, *Plasmodium vivax*, is representative of the class *Sporozoa*. It has two hosts, the *Anopheles* mosquito and man. An infected female anopheline mosquito introduces sporozoites into human blood when it feeds through the skin. In about seven to ten days these sporozoites are found inside the blood cells of their new human host. They grow and divide by asexual fission and in forty-eight hours burst the cell and circulate within the blood stream of the host. They repeat this cycle until the human host has many blood cells being infected and bursting at the same time. This is what causes the typical symptoms of recurring chills and fever of malaria.

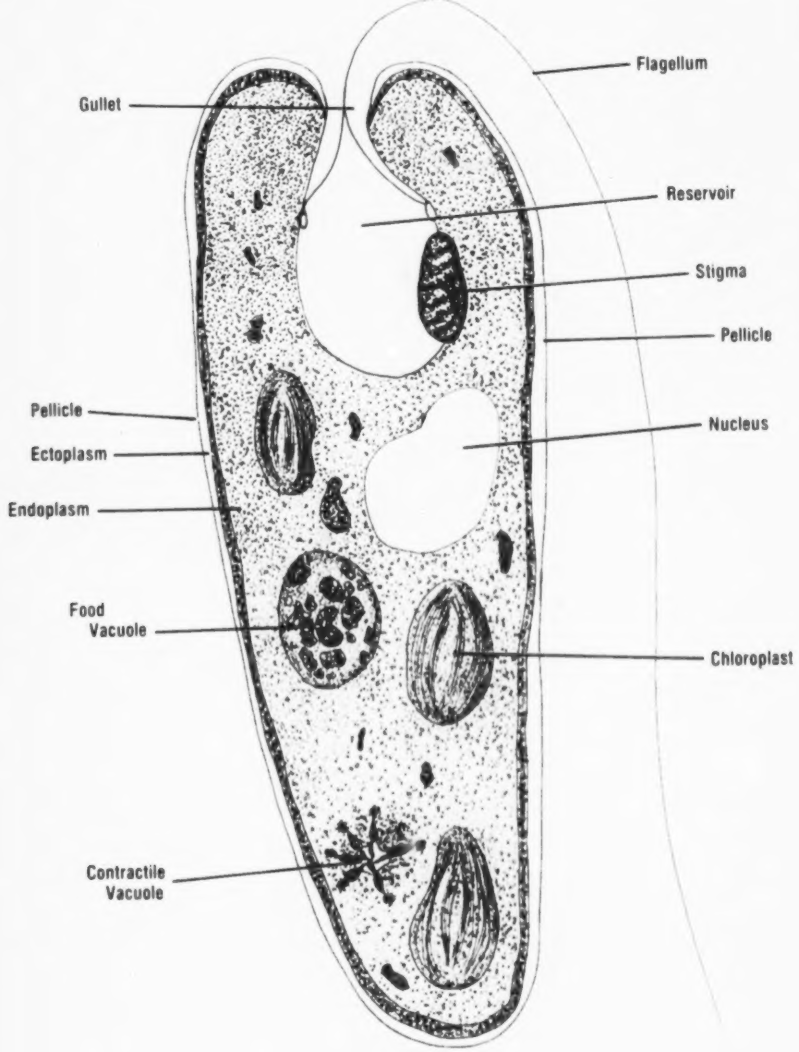
Some of the parasites do not simply grow and divide while in man but also undergo meiosis. These haploid gametes wait in the human host until a female mosquito takes in blood from the infected human. The gametes fuse into sporozoites within the digestive tract of the mosquito. When the mosquito bites again, introducing sporozoites into another human, the life cycle of *Plasmodium vivax* repeats.

Mastigophora

All *Mastigophora*, commonly known as the flagellates, move by one or more flagella, long whip-like organelles which slap back and forth in water pulling or pushing the protozoa. Some *Mastigophora* contain chlorophyll and produce their own energy by photosynthesis, while others consume organisms, dead or alive. Some, such as *Euglena*, may feed in both ways, depending upon food availabilities, and some, such as *Trypanosoma*, are parasites. The parasitic *Trypanosoma* has a two host life cycle similar to malaria, alternating between the tsetse fly and humans. It causes African sleeping sickness, a scourge which renders parts of tropical Africa dangerous to human life.

Although *Mastigophora* genera differ in many other respects, all carry flagella for locomotion. Nearly all *Mastigophora* reproduce asexually by simple longitudinal fission. Sexual reproduction occurs in only a few species.

Species of the genus *Euglena* inhabit stagnant pools, ditches and streams, sometimes becoming so abundant as to produce a green surface bloom or green spots on the bottom ooze. They may be easily collected, grown, and observed in the laboratory. Study figure two below, noting the typical structures of *Euglena terricola*.



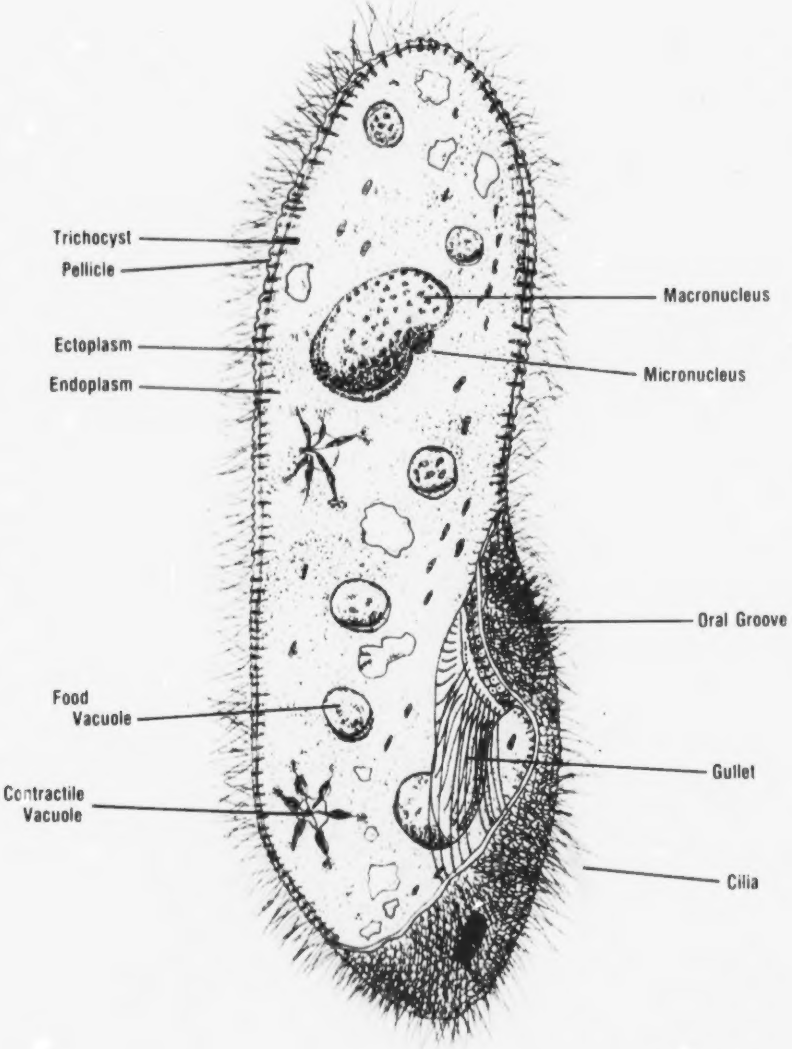
Euglena terricola

Figure 2

Ciliata

The ciliates are the most structurally complex protozoa. They move by means of hundreds of tiny, hair-like organelles called cilia. Cilia beat like whips in a smooth wave-like motion, and they enable a ciliate to move quickly across a microscope's field of view. Some cells in multicellular organisms are also ciliated, such as the cells which line the human esophagus. Cilia in protozoa also function in food gathering. All ciliates have two kinds of nuclei, a macronucleus and a micronucleus. They are either hunters or scavengers of other organisms. They reproduce asexually by binary fission or budding and sexually by conjugation. The micronucleus plays an important role in their sexual reproduction. The majority of the ciliates are free-living, but there are some parasitic forms. The ciliates live wherever water is available.

Study figure three below, noting the typical structures of the ciliated *Paramecium caudatum*.


Trichocyst
Pellicle
Macronucleus
Ectoplasm
Endoplasm
Micronucleus
Oral Groove
Food Vacuole
Gullet
Contractile Vacuole
Cilia

Paramecium caudatum

Figure 3

In this laboratory you will study living protozoa, noting their shape, structure, and movement. You also will study prepared slides of protozoa in order to observe behavior and types not available live in the laboratory.

Pre-lab

Supplies needed:

Equipment

microscope
eye dropper
2 cover slips
microscope slide
concave microscope slide
prepared slide of conjugating *Paramecium bursaria*
prepared slide of *Plasmodium vivax* or *falciparum*

Materials

Amoeba proteus
Euglena terricola
Paramecium caudatum
slowing agent
lens paper

Special Preparations

1) Order fresh cultures of protozoa to arrive within two days of the laboratory. Immediately place cultures of *Amoeba* and *Paramecium* in a closed cupboard. Place the container containing *Euglena* in an area of diffused light. Loosen container lids so that oxygen is freely available. Periodically aerate the containers by bubbling with an eyedropper. Place a grain or two of rice in the *Amoeba* container and a grain or two of boiled wheat in the *Paramecium* container.

Alternatively, you can culture these protozoa yourself from wild cultures. *Amoeba* eat debris (they will cluster around rice grains placed at the bottom of a pond), *Paramecium* feed on bacteria (they can be found in pond surface waters), and *Euglena* prefer to photosynthesize (they also are found in pond surface waters).

If you live near a slaughter house, ciliates from cattle stomachs can be removed and placed in a thermos. The ciliates will remain active and alive until the thermos cools. Students enjoy observing these ciliates as an optional activity.

2) Provide one culture dish of each organism for the whole class. Clearly label the eye dropper provided with each species so that students do not mix cultures when removing their specimens.

3) Commercial preparations of slowing agents are available, such as Protoslo. Alternately, you can make a slowing agent by dissolving 10 g. methyl cellulose in 90 ml. water.

Time Required

The protozoa laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. On a clean, concave slide place a drop of *Amoeba* culture taken from the bottom or sides of the culture jar. (*Amoeba* are so large that they would be squashed by placing a cover slip on a regular slide.) Gently place a clean cover slip on the concave slide. Reduce the illumination on your microscope as much as possible, and search for an *Amoeba* by moving the slide slowly back and forth. When you find one, switch to high power to study detailed structures.

Distinguish the following structures:

- Pseudopodia: blunt projections of the cell body.
- Ectoplasm: a thin, clear layer of cytoplasm surrounding the body just inside the plasma membrane.
- Endoplasm: a more granular cytoplasm, inside the ectoplasm.
- Food vacuoles: these are found within the cytoplasm. Their sizes vary, and their contents are surrounded by clear fluid.
- Contractile vacuoles: these are seen as round, clear forms which appear and disappear.
- Nucleus: a disc-like structure toward the center of the organism.

1. Describe the movement of the *Amoeba*

2. Describe any solid materials going in or out of the *Amoeba*. Is this material food?

3. Describe the growth, and then expulsion, of a contractile vacuole.

B. Obtain a prepared slide of *Plasmodium*, and observe it under both low and high power of the microscope.

4. Where, on the slide, do you find the *Plasmodium?*

5. Draw, in the space provided below, *Plasmodium* in different stages of maturity, as they are represented on your prepared slide.

C. Place a drop of *Euglena* culture taken from the top of the culture jar on a clean slide. Add a drop of slowing agent. Gently place a clean cover slip on the slide. Study *Euglena* under bright illumination. Search for a *Euglena* by moving the slide slowly back and forth. When you find one, switch to high power to study detailed structures. Despite the slowing agent, the *Euglena* may continue to move in and out of your field of view.

Distinguish the following structures:

- Anterior (blunt) and posterior (tapered) ends.
- Flagellum: this is at the anterior end. It is long and thread-like and may show up better with reduced illumination.
- Gullet and reservoir: at the anterior end.
- Pellicle: a thin cell covering, inside of which is a narrow band of ectoplasm, and then the endoplasm, in which cell organelles are embedded.
- Stigma: near the reservoir; a small, red eyespot.
- Chloroplasts: green structures throughout the cell endoplasm.
- Contractile vacuole: star-shaped and slender when empty, bulging when full.
- Nucleus: near the center of the cell.

6. *Euglena* move in three ways. Describe these movements. ______________________________

____

____

____

____

7. What end of the *Euglena* is regularly directed forward? ______________________________

8. Is the cell body consistently of the same shape? ______________________________

9. What is the response of *Euglena* to light? ______________________________

____

10. What are the gullet and reservoir of the *Euglena* used for? ______________________________

____

____

11. In what respects is the *Euglena* animal-like, and in what respects is it plant-like? ______________________________

____

____

____

____

____

____

D. Place a drop of *Paramecium* culture taken from the top of the culture jar on a clean slide. Add a drop of slowing agent. Gently place a clean cover slip on the slide. Study *Paramecium* under reduced illumination. Search for a *Paramecium* by moving the slide slowly back and forth. When you find one, switch to high power to study detailed structure. Despite the slowing agent, the *Paramecium* may continue to move in and out of your field of view.

Distinguish the following structures:

- Anterior (blunt) and posterior (tapered) ends.
- Cilia: these cannot actually be seen with a light microscope, but you can indirectly detect their presence by noting turbulence in the fluid around the organism.
- Oral groove: a diagonal indentation extending from the anterior end.
- Pellicle: a thin cell covering, inside of which is a narrow band of ectoplasm, and then the endoplasm in which cell organelles are embedded.
- Food vacuoles: through the endoplasm, often extending from the oral groove.
- Contractile vaculoes: similar to those found in *Euglena*.
- Macronucleus and micronucleus: near the center of the cell, usually in close proximity to each other.

12. Describe the movements of *Paramecium* ____________________

13. Does the shape of *Paramecium* change as it moves? ____________________

14. What does the *Paramecium* you are observing appear to be doing? ____________________

E. Obtain a prepared slide of conjugating *Paramecium*. Study it under both low and high power of the microscope.

15. Draw, in the space provided below, conjugating *Paramecium*. Label all structures. Describe conjugation in *Paramecium*.

16. Compare *Amoeba*, *Plasmodium*, *Euglena*, and *Paramecium*, using the following criteria:

Shape ____________________

Speed ____________________

Feeding and digestion ____________________

17. Work the puzzle, figure four below. See how many protozoan terms you can find.

Protozoa Puzzle

A	B	X	C	T	D	Y	S	V	N	O	J	C	C	O	N	J	U	G	A	T	I	O	N
R	I	N	E	A	U	S	T	O	P	R	I	M	A	T	E	D	A	C	Y	N	L	L	B
O	A	S	E	X	U	A	L	A	H	M	Y	J	Y	V	U	L	B	I	E	A	N	E	I
A	H	S	C	O	T	L	K	E	Y	N	O	E	I	N	D	M	C	I	K	O	E	O	F
K	I	B	I	N	O	M	I	A	L	N	O	M	E	N	C	L	A	T	U	R	E	V	A
L	S	G	H	O	O	Z	N	A	U	R	Y	O	G	P	L	A	S	M	O	D	I	U	M
N	D	H	O	M	H	H	G	V	M	E	V	R	D	N	A	U	D	D	J	E	D	S	I
H	S	Z	O	Y	N	L	D	V	R	M	G	E	N	U	S	V	M	B	K	R	T	T	L
E	L	C	A	N	A	L	O	G	O	U	S	W	R	S	S	P	E	C	I	E	S	D	Y
T	M	H	J	N	M	K	M	P	I	T	C	N	K	P	A	R	A	M	E	C	I	U	M
E	A	O	R	R	K	B	D	R	A	U	T	O	L	O	C	O	M	O	T	I	O	N	W
R	S	T	L	I	E	P	V	F	K	A	E	D	S	R	T	T	E	S	B	U	H	L	L
O	T	S	S	O	U	P	F	X	C	L	W	V	P	E	C	I	L	I	A	T	A	O	R
T	I	L	G	R	G	Z	X	M	T	I	S	S	S	Y	L	S	C	E	M	C	U	G	T
R	G	B	F	K	L	O	U	G	V	S	V	T	E	B	V	T	F	V	O	N	T	W	S
O	O	H	S	I	E	N	U	T	U	M	A	S	U	T	D	A	G	E	E	R	B	A	P
P	P	B	U	R	N	M	A	S	A	R	C	O	D	I	N	A	H	T	B	V	T	I	C
H	H	I	P	B	A	G	B	O	D	S	U	V	O	I	I	L	O	R	A	L	R	H	I
V	O	L	V	O	X	J	J	V	T	E	O	E	P	T	B	I	I	G	R	O	O	V	E
T	R	L	Z	C	F	O	R	S	V	N	L	G	O	R	Q	N	J	L	T	U	P	S	Y
P	A	R	A	S	I	T	E	E	N	J	E	C	D	S	P	O	K	M	V	W	A	Z	A
D	Y	R	A	N	I	B	F	B	I	N	A	R	Y	F	I	S	S	I	O	N	B	D	E

Figure 4

Resources

Carolina Biological. *The Protozoa.* #48-1518, slides with cassette.

Leonard, Jonathan A. "The Queen of Diseases Strikes Back," *Johns Hopkins Magazine*, July-August 1979.

Yoe, Mary Ruth. "The Horror," *Johns Hopkins Magazine*, February 1981.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- *Amoeba*
- *Euglena*
- cilia
- *Ciliata*
- conjugation
- fission
- flagella
- *Mastigophora*
- *Paramecium*
- pellicle
- *Plasmodium*
- protozoa
- pseudopodia
- *Sarcodina*
- *Sporozoa*
- vacuole

Review

26. Protozoa

Name______________________________

Date______________________________

Multiple choice

______ 1. Protozoa are classified by means of
a. locomotion
b. reproduction
c. digestion
d. respiration

______ 2. A macronucleus is found in the
a. *Paramecium*
b. *Amoeba*
c. *Euglena*
d. *Volvox*

______ 3. The *Mastigophora* move by means of
a. pseudopods
b. flagella
c. cilia
d. contractile vacuoles

______ 4. The *Sarcodina* reproduce by
a. longitudinal binary fission
b. transverse binary fission
c. simple fission
d. conjugation

______ 5. The protozoa that has a specific structure for excretion is the
a. *Paramecium*
b. *Amoeba*
c. *Euglena*
d. *Volvox*

______ 6. The protozoa that collects food through its oral groove is the
a. *Paramecium*
b. *Amoeba*
c. *Euglena*
d. *Volvox*

______ 7. Two nuclei are located near the center of this protozoa:
a. *Paramecium*
b. *Amoeba*
c. *Euglena*
d. *Volvox*

______ 8. A pellicle is
a. a type of nucleus
b. another name for a gullet
c. an outer membrane
d. a type of reproduction

______ 9. The protozoa capable of producing its own food is the
a. *Paramecium*
b. *Amoeba*
c. *Euglena*
d. *Sporozoa*

______ 10. Conjugation is characteristic of
a. *Paramecium*
b. *Amoeba*
c. *Euglena*
d. *Volvox*

______ 11. The micronucleus of *Paramecium* functions in
a. reproduction
b. locomotion
c. metabolism
d. sensitivity

______ 12. A long, whip-like thread of cytoplasm used for locomotion is a
a. pseudopod
b. pellicle
c. flagella
d. cilia

______ 13. A cavity for discharging excess water and gases from the cell is a/an
a. excretory pore
b. trichocyst
c. food vacuole
d. contractile vacuole

______ 14. Cytoplasmic projections called false feet are
a. cilia
b. flagella
c. macronuclei
d. pseudopods

______ 15. A *Sarcodina* is a class of
a. dog
b. *Amoeba*
c. *Homo sapiens*
d. *Paramecium*

______ 16. If you had a reservoir you would be a
a. *Paramecium*
b. *Amoeba*
c. *Euglena*
d. *Volvox*

______ 17. Which organism reproduces using the process of longitudinal binary fission?
a. *Paramecium*
b. *Amoeba*
c. *Euglena*
d. *Sporozoa*

______ 18. The only type of protozoa which does not exhibit a type of locomotion is
a. *Paramecium*
b. *Amoeba*
c. *Euglena*
d. *Sporozoa*

______ 19. The same function is served in different protozoa by cilia and
a. bacilli
b. plasmodia
c. flagella
d. cocci

______ 20. Among protozoa, the same individual in some species may be both
a. aquatic and terrestrial
b. a micro and macroorganism
c. parasitic and free-living
d. a producer and a consumer

27. Laboratory

Sponges

When you have completed this laboratory you should be able to:

1. Identify the structures of a simple sponge.
2. Determine how the structures of a sponge relate to its life functions.
3. Understand the life cycle of a sponge.

Phylum *Porifera*

The sponge is the simplest of all multicellular animals. Its body is composed of only two cell layers, an epidermis and an endodermis, and these cell layers are covered with pores or holes called ostia. The ostia give the sponges their phylum name, *Porifera*, which means "pore bearing."

Sponge Structure

Because every cell in the body of a sponge is in direct contact with the water environment, it has no need for a respiratory or excretory system, or for specialized organs. Sponges also have no nervous net or system, and they appear not to respond to stimulus. Most sponges are marine organisms, with only a few living in fresh water. All sponges are sessile, that is, they are permanently attached to one place. Most sponges exhibit radial symmetry.

In addition to ostia in the epidermal and endodermal cells, sponges have internal canals for the flow of water throughout the animal. The central cavity of the sponge is called a spongocoel. Every sponge has one or more large openings at the superior, or top end called oscula. The oscula function as exhaust ports for the return of water to the environment. This water vascular system has a large capacity for moving water through the sponge. In larger, more advanced sponges, it is estimated that an amount of water equal to the volume of the sponge is pumped through the animal each and every minute.

Although certain cells in the sponge perform specialized functions, to the benefit of the total organism, these cells can live separately if cut or broken off. The separated cells also can reform into a new sponge. Therefore, while the sponge is classed as a multicellular animal, it is multicellular in the minimal sense of the word.

Digestion

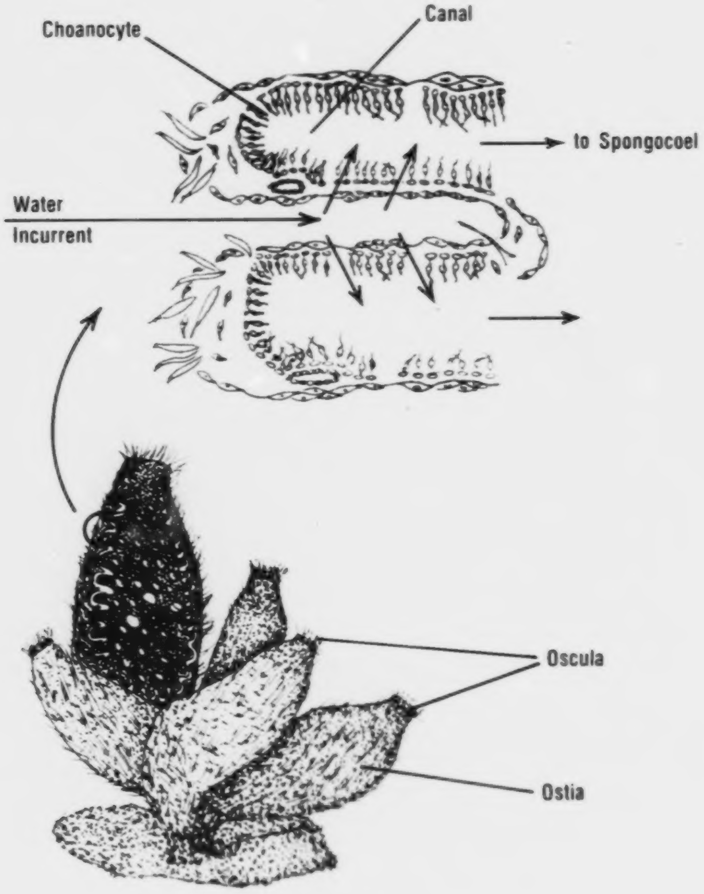
Food is taken from water which flows into the sponge through the ostia, or incurrent pores, and circulates through the canals. Organic debris and microorganisms are drawn in by water currents created by the moving flagella of choanocytes. Choanocytes, or flagellated collar cells, line the endodermal cavities of the sponge. Choanocytes can digest some of this floating food in their food vacuoles. Choanocytes lining the inside of the sponge can be thought of as a primitive gastrodermis, or "stomach layer."

Undigested food is passed from the choanocytes into the mesoglea, or the area between the two cell layers. The mesoglea, really a jelly-like matrix, is not a third cell layer, because its contents are not arranged in an organized fashion. However, amoebocytes, or amoeba-like cells, live in the mesoglea, and they digest the remaining food particles.

Amoebocytes are the "fix-it men" of the sponge. Not only do they digest food particles, and, by moving about the mesoglea, distribute the digested food to all parts of the sponge, but they also secrete the gelatinous matrix composing the mesoglea. Some amoebocytes remove wastes from the mesoglea, and some fill in for choanocytes that for some reason have been scraped off the animal. Still others can function like muscle cells arranged around the oscula, if it is necessary to regulate the flow of water in the sponge.

Biologists have speculated as to whether amoebocytes are really a form of *Amoeba* and choanocytes are really choanoflagellates which have, in the distant past, banded together to their mutual benefit and, in the process, formed the first multicellular animal.

Figure one below illustrates sponge structures.



Sponge Colony

Figure 1

Skeleton and Classification

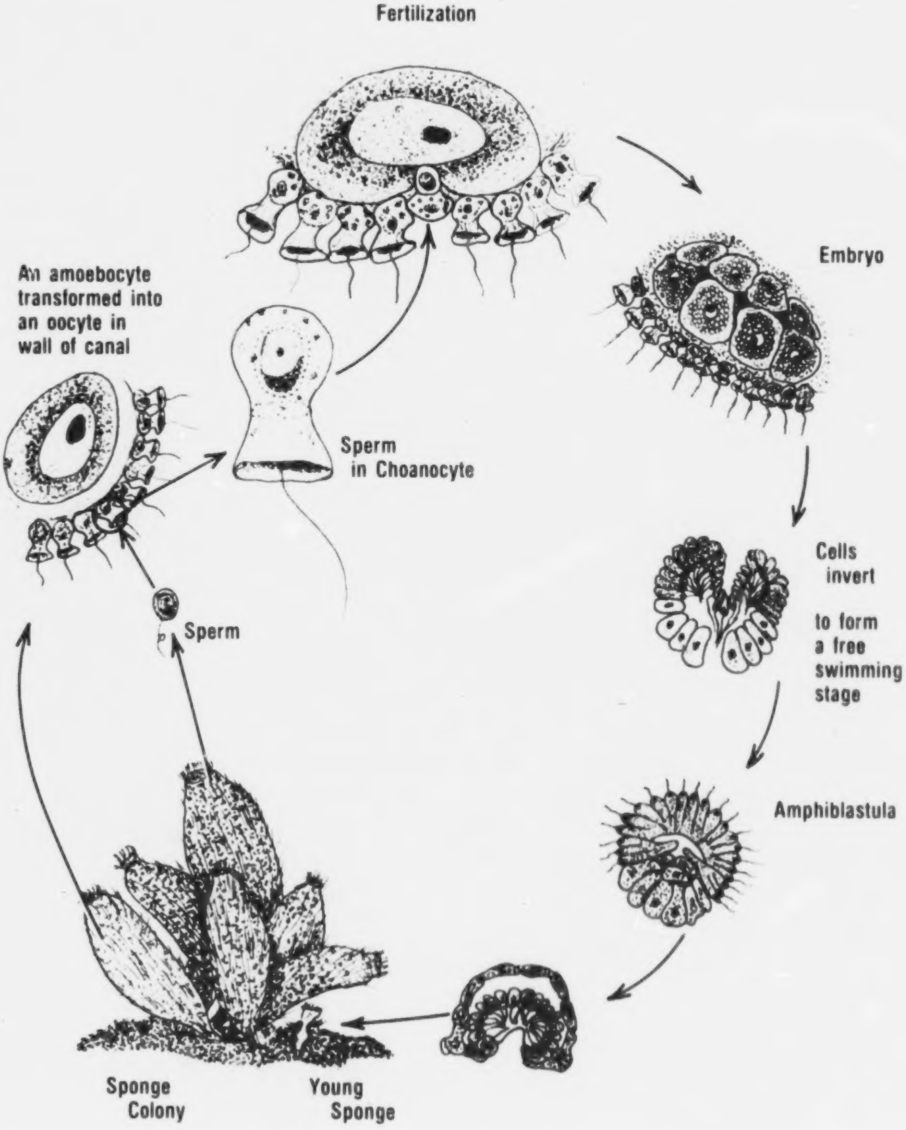
The skeleton of a sponge is formed between its two cell layers, in the mesoglea where the amoebocytes live. The skeleton is composed of spicules which may have from two to six points. The basic classification of a sponge is by the type of material which composes its skeleton. The *Calcarea*, or chalk sponges, have spicules composed of calcium carbonate, the *Hexactinellida*, or glass sponges, have six pointed spicules made of silicon, and the *Demospongia*, or horny sponges, have spicules made of silicon and/or a protein fiber called spongin.

Chalk sponges are found on rocks and other debris in tidal pools and shallow water. Glass sponges are found only in deep waters, but sometimes they are washed ashore after storms. Horny sponges are found in various water environments. If the spicules of horny sponges are composed of silicon, or a mixture of silicon and spongin, they are known as boring sponges; or encrusting organisms. Boring sponges attach themselves to debris or shells and bore into these objects by slowly dissolving them. If the spicules are composed entirely of spongin, they are known as bath sponges. These are in commercial demand because of their spongy, pliable skeletons.

Reproduction

Sponges reproduce asexually in three ways. If a part of the sponge is broken off, the separated part will grow and form a new sponge. This is not surprising, since the sponge is such a loosely aggregated collection of cells. Sponges also reproduce asexually by budding, or growing tiny sponges at the base of a more mature specimen. The buds break off and float away to take hold and form new sponges. Finally, some sponges, including freshwater sponges, can reproduce by surrounding balls of cells with a protective capsule. These balls are called gemmules. The gemmules are released when the parent sponge dies and decays. The gemmules float off and grow into new sponges.

Although most sponge reproduction is asexual, sponges also are able to sexually reproduce. Sponges produce both sperm and eggs and fertilization is internal. This is detailed in figure two below.


Fertilization
Embryo
An amoebocyte transformed into an oocyte in wall of canal
Sperm in Choanocyte
Cells invert to form a free swimming stage
Sperm
Amphiblastula
Sponge Colony
Young Sponge

Sponge Life Cycle

Figure 2

Pre-lab

Supplies needed:

Equipment

microscope
microscope slide
coverslip
prepared slide of *Grantia*
prepared slide of gemmules
eye dropper
dissecting scope or hand lens
scissors
watch glass
probe
2 dissecting needles

Materials

Grantia
chlorine bleach
lens paper

Special Preparations

1) Prepared slides: the *Grantia* slide should be a cross section slide showing choanocytes on radial canals. The gemmule slide should be a whole mount slide. These are usually produced using *Spongilla*.

2) Preserved specimens of *Grantia* are available from most biological supply houses. Purchase only those at least two centimeters in length, so that they are large enough for student dissection.

3) Students need use only one or two drops of bleach per laboratory group. The bleach is easily dispensed from a central station.

Time Required

The sponges laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Obtain a specimen of *Grantia*, a simple marine sponge, and place it in a watch glass. Study the outer surface of the animal with the aid of a dissecting scope, or hand lens, and a probe.

Identify the following external features:

- Base: the attached end.
- Osculum: found at the top.
- Ostia: pores in the body of the sponge.
- Bud: found near the base, if present.

1. What feature places it in the phylum *Porifera*?

____

2. What are the paths of water currents in your *Grantia* specimen?

____

____

B. Insert the point of your scissors into the osculum, and carefully cut the animal lengthwise. Use a dissecting scope or hand lens to study the inside of the sponge.

Identify the following internal features:

- Spongocoel: the large, internal cavity.
- Osculum: exit from the spongocoel.
- Ostia: pores in the body wall.
- Spicules: hardend areas in the body wall.
- Incurrent canals: connected to the ostia.
- Radial canals: connected to the spongocoel.

3. Can you identify two layers of cells?

4. Describe water paths through your specimen.

5. What produces water currents? What essential functions do they perform in the organism?

6. How does the sponge obtain food? Where and how is the food digested?

7. What advances does a sponge show over a colonial protozoa?

C. Use dissecting needles to separate the cells of your animal. Place some of these cells on a microscope slide in a drop of water, and cover with a coverslip. Observe under both low and high power of the microscope.

8. Draw what you see in the space provided below. Label all identifiable structures.

D. Study a prepared cross section slide of *Grantia*.

9. Draw what you see in the space provided below. Identify all cellular structures, and label them in your drawing.

E. Determine the class of *Grantia* which you dissected by testing its type of spicule. Remove the coverslip on your slide, and carefully add one drop of chlorine bleach. Calcareous spicules will dissolve in bleach, but silicious and spongin spicules will not.

10. What material constitutes the spicules of your specimen?

F. Study a prepared slide of gemmules under both low and high power of your microscope.

11. Draw what you see in the space provded below. Identify all cellular structures, and label them in your drawing.

12. What are gemmules?

Resources

Belinky, Charles R. and Jan L. Wassink. "Sponges, Anemones, Corals, and Flatworms," *Survey of the Animal Kingdom: The Invertebrates*. #FS 1058, one part of a four part filmstrip series with cassettes and guides. Educational Images, Ltd.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

amoebocyte
budding
choanocyte
endodermis
epidermis
gemmule
mesoglea
oscula
ostia
Porifera
radial symmetry
spicule
spongin
spongocoel

Review

27. Sponges

Name______________________________

Date_______________________________

Fill in the blanks

Sponges belong to the phylum **1.** ____________________ which means **2.** ____________________ . They inhabit, for the most part, **3.** ____________________ water and therefore are marine animals. Since they are permanently attached to a substratum and do not move, they are said to be **4.** ____________________ . The sponge has **5.** ____________________ symmetry because it has similar parts arranged around a central disc. The body has many **6.** ____________________ or ostia which permit the passage of water. The sponge also has two definite layers of cells, the **7.** ____________________ and the **8.** ____________________ . In between these layers is the **9.** ____________________ which is an indefinite gelatinous mass that contains other structures. The opening to the outside which allows water to pass out is called the **10.** ____________________. The central cavity is the **11.** ____________________ , and it is the hollow part of the organism. **12.** ____________________ are structures that give support to the sponge. They may be composed of **13.** ____________________ , **14.** ____________________ , or **15.**____________________ . Sponges whose **16.** ____________________ are made of **17.** ____________________ are treated and used commercially.

The food of the sponge consists of **18.** ____________________ and **19.** ____________________ . It is drawn in along with **20.** ____________________ through the **21.** ____________________ . Currents of water are created by **22.** ____________________ . The **23.** ____________________ can digest some of the food in vacuoles. Undigested food is passed into the mesoglea where **24.** ____________________ digest it and transport nutrients to other parts of the organism.

The sponge has no special structures for the process of respiration. **25.** ____________________ comes in through the **26.** ____________________ with water. The **27.** ____________________ deliver it to other parts of the sponge and receive **28.** ____________________ to be passed out of the **29.** ____________________ along with used water.

The sponge can reproduce **30.** ____________________ in three ways. These methods are by **31.** ____________________ , **32.** ____________________ and **33.** ____________________ . The sponge can also reproduce **34.** ____________________ , by producing sperms and eggs. Fertilization is **35.** ____________________ . The sponge does not have a nervous system and therefore shows few responses to stimuli.

28. Laboratory

Hydra

When you have completed this laboratory you should be able to:

1. Understand the life cycle of jellyfish, sea anemones, coral, and hydroids.
2. Analyze the structure of a hydra.
3. Observe the behavior of a living hydra.

Phyla *Coelenterata* and *Ctenophora*

The phylum *Coelenterata*, which means "hollow intestine," includes hydras, some of the jellyfish, corals, and sea anemones. The related phylum *Ctenophora* comprises the combed jellies. Creatures in these two phyla are mostly marine animals, and they number over 10,000 species.

The jellyfish are the largest and most familiar of the plankton floating in the ocean. Plankton consists of all passive marine organisms which float with the currents. They may swim, but not strongly enough to stay in one place against a current. The jellyfish fit this definition of limited ability to move.

The *Coelenterata* and *Ctenophora* are characterized by two layers of tissue separated by a mesoglea. They possess the first true nerve cells among lower invertebrates, with the cells arranged in a net. They also have specialized stinging structures called nematocysts. Such increasingly specialized cells permit the members of the two phyla to react actively to their surroundings and to hunt for food.

The coelenterate jellyfish have tentacles with nematocysts, and they swim by muscular contractions of an umbrella-shaped body. All coelenterates are radially symmetrical. The ctenophore jellyfish exhibit bilateral symmetry and have only two tentacles with adhesive cells. They move by the beating of numerous combs, each of which is a row of fused cilia. Some biologists think that the coelenterates and ctenophores are too similar to be placed in two separate phyla.

Both phyla reproduce asexually by budding and regeneration. They also exhibit a sexual life cycle that undergoes a well defined alternation of generations, that is, they reproduce asexually and sexually in phases that alternate with each other. This differs from the alternation of generations that occurs in plants, where the alternating body plans are haploid and diploid. In the coelenterates and ctenophores both polyp and medusa body plans are diploid, as in all multicellular animals, and only the gametes are haploid. Two different body plans are involved during alternation of generations. The diploid form of most coelenterate species is a polyp, and their alternate form is a medusa (or a comb jelly in the ctenophores). Sea anemones, which have tubular bodies, are coelenterate polyps, and their alternate form is a jellyfish which has an umbrella-shaped body. Polyps are slow moving or sessile, and medusae are free-swimming.

The well known Portuguese Man 'O War, which can sting a man to death, is a very large coelenterate. However, it is not a true jellyfish, but rather it is a colony of polyps which hang upside down from a gas-filled bag secreted by the colony.

For a typical coelenterate body plan, study figure one:

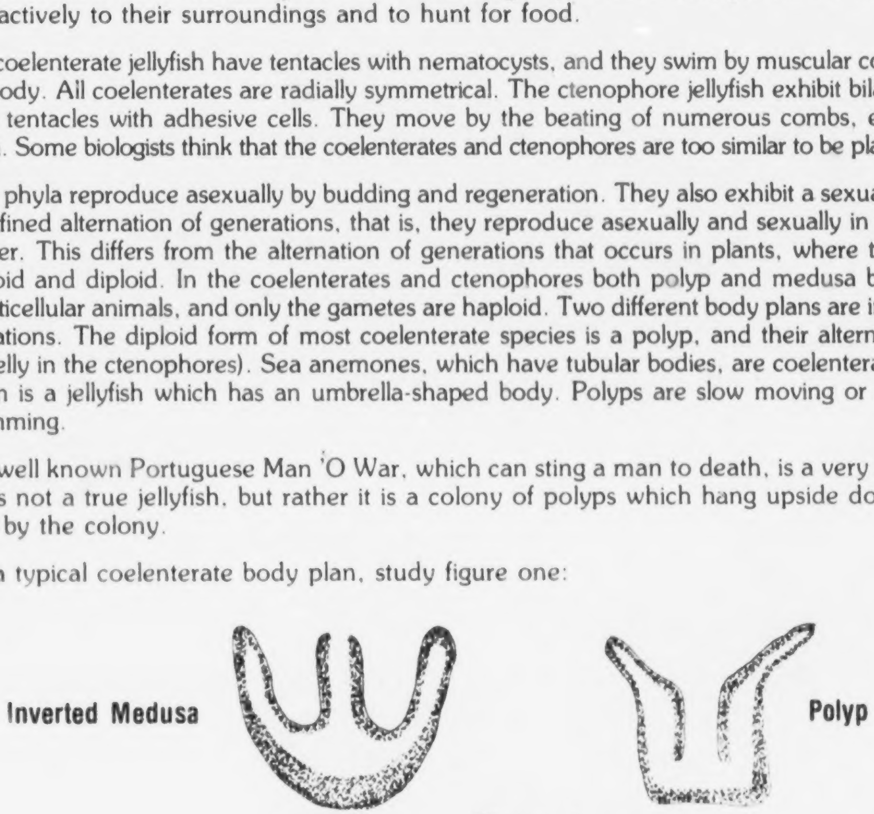


Figure 1

Coelenterate Classification

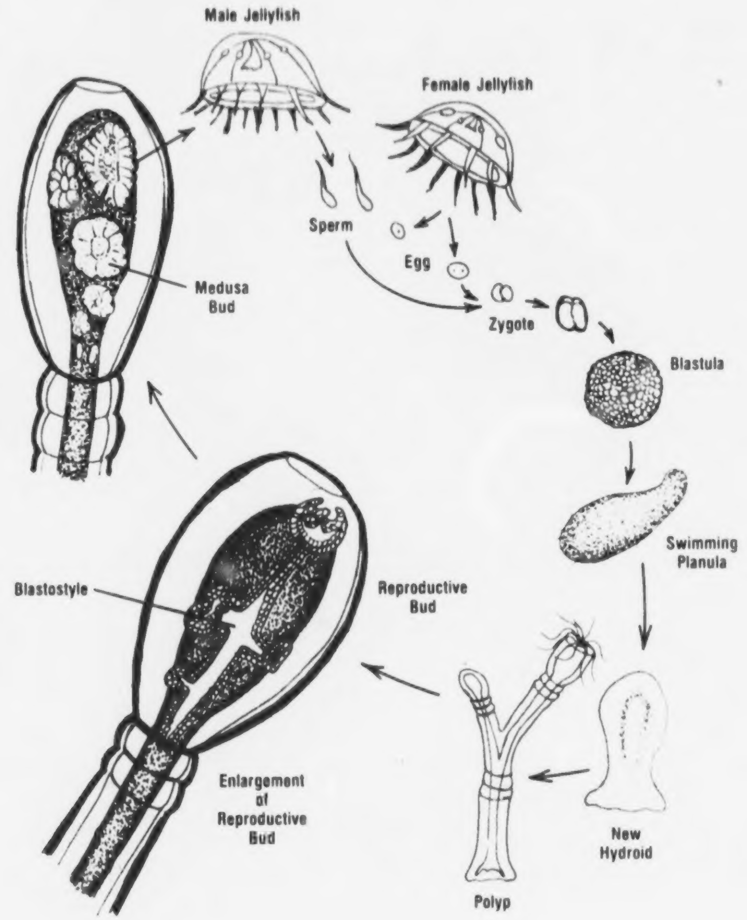
The *Coelenterata* are classified according to their life history and structure. Generally, those species which alternate between a medusa and a polyp body plan belong to the class *Hydrazoa*. Those species which live primarily as medusae belong to the class *Scyphozoa*, and those species which live primarily as polyps to the class *Anthozoa*.

Hydra

The *Hydra* are freshwater polyps belonging to the class *Hydrazoa*. They are commonly found attached to plants or stones in ponds and streams. They may be brown, green, or white.

The body of the animal is long and slender, with arm-like tentacles attached to the top. The bottom of the body, called the base or basal disc, attaches the animal to surfaces in the water. Unlike some polyp forms, *Hydra* are not sessile. *Hydra* can move slowly by gliding on their base, or rapidly by a somersaulting action. To somersault, the animal attaches its tentacles near the base and swings its body over the top.

Like all coelenterates, some species of *Hydra* are dioecious, that is, with both male and female sex organs on the same animal, and some are monecious, that is, with separate male and female forms. The sexual life cycle of a hydroid animal is outlined in figure two below.


Male Jellyfish
Female Jellyfish
Sperm
Egg
Medusa Bud
Zygote
Blastula
Swimming Planula
Blastostyle
Reproductive Bud
Enlargement of Reproductive Bud
New Hydroid
Polyp

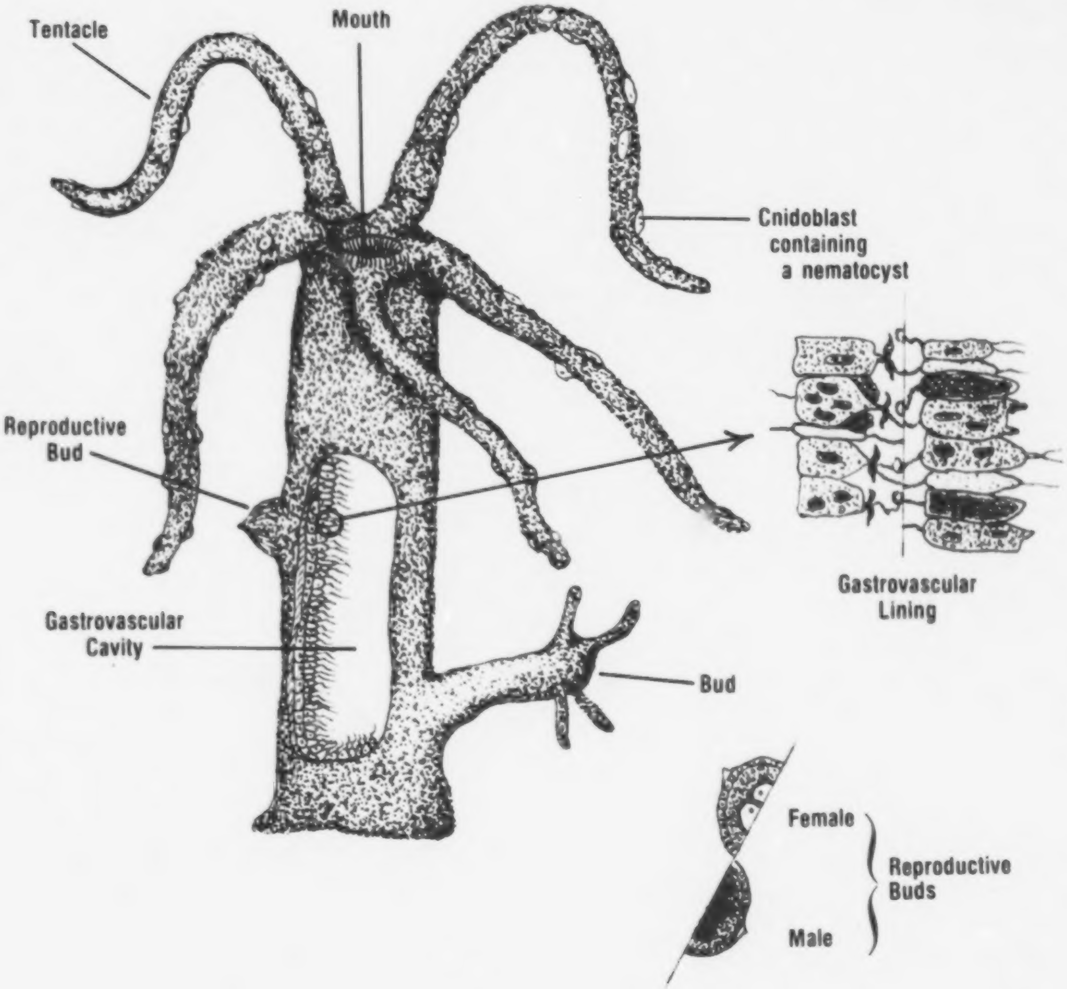
Hydra Life Cycle
Figure 2

Cell Specialization

Like all coelenterates, and the sponges, *Hydra* have two cell layers, an epidermis and an endodermis. However, coelenterate cell layers contain several types of specialized cells. Besides the epidermal layer itself, the tentacles carry stinging nematocysts contained within cells called cnidoblasts. When a small animal comes in contact with the tentacles, it is paralyzed by the nematocysts, and the animal is able to capture and devour it. Other specialized epidermal cells are muscle cells. *Hydra*, for instance, possess coarse longitudinal muscle fibers which run the length of the body and tentacles. *Hydra* also possess a nerve net which contains both sensory cells and motor cells. *Hydra* have glandular secretory cells on their base, or basal disc, and reproductive cells.

The endodermal cells of *Hydra* and the coelenterates have specialized into gastrodermal cells. These line the stomach cavity and are muscular cells, flagellated cells, and mucous gland cells. The body cavity contains food, water, and extracellular digestive juices.

Study figure three below which illustrates the overall structure and some of the specialized cells of *Hydra*.


Tentacle
Mouth
Cnidoblast containing a nematocyst
Reproductive Bud
Gastrovascular Lining
Gastrovascular Cavity
Bud
Female
Male
Reproductive Buds

Hydra
Figure 3

During this laboratory you will study the polyp form of *Hydra*, a freshwater member of the *Hydrazoa*. Although *Hydra* can be collected from freshwater ponds and streams, your instructor probably will purchase them from a biological supply house.

Pre-lab

Supplies needed:

Equipment

dissecting scope
penlight or small flashlight
eye dropper

microscope
watch glass
probe

prepared slide of *Hydra* cross section with nematocysts

Materials

Hydra

Daphnia

6 X 6 cm. piece blue cellophane

Special Preparations

Arrange to have the *Hydra* and *Daphnia* (water fleas) delivered shortly before the day of the laboratory. Immediately aerate upon receipt (like you did with the live materials in laboratory twenty-six), and place in a cupboard until class.

Time Required

The *Hydra* laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Using an eye dropper, carefully transfer a *Hydra*, along with enough culture water to cover the animals, to a watch glass. Study the *Hydra* using a dissecting scope with as little light as possible. Allow the animal a few minutes to adjust to this new environment. As it adjusts, it will begin to stretch out and search for food.

Identify the following external features:

- Body column and cavity.
- Basal disc: for attachment.
- Tentacles.
- Bud: if present.
- Nematocysts: these are very tiny, but groups of them appear like lumps on the tentacles.
- Mouth.

1. How many tentacles are on your specimen? ______________________________

2. What was the original position of the animal when you first observed it? ______________________________

____

3. After a few minutes of observation the *Hydra* will move. What changes occur in its shape as it moves?

____

____

4. How does the *Hydra* move? ______________________________

____

____

5. What happens to the *Hydra* if you slightly move the watch glass? ______________________________

____

____

6. What happens to the *Hydra* if you gently and lightly touch it with your probe? Describe what happens.

____

____

____

7. Did you observe anything to indicate that the probe stimulus spread to areas distant from the contact? Explain.

____

____

____

B. Shine a light on the *Hydra* from one side of the watch glass.

8. What is the reaction of the *Hydra* to the light? ______________________________

____

____

9. Repeat step B, but shine the light through a 6 X 6 cm. piece of blue cellophane. What is the reaction this time?

____

____

____

C. Use an eye dropper to catch a few water fleas, *Daphnia*, and transfer them to the watch glass containing your *Hydra* specimen. Observe what happens with the aid of your dissecting scope. Again, give the *Hydra* a few seconds to adjust to this new situation.

10. Describe how a *Hydra* captures a *Daphnia*. ______________________________

____

____

____

____

11. What evidence indicates that the *Hydra* used its nematocysts on the *Daphnia*? ______________________________

____

____

____

12. Describe how a *Hydra* eats. ______

13. Do you think a *Hydra* coordinates its movements? Explain. ______

14. Compare the feeding of *Hydra* with that of a sponge. ______

D. Use a microscope to examine a prepared cross-section slide of the tentacles of a *Hydra* with nematocysts.

15. In the space provided below, draw an example of a *Hydra* nematocyst embedded in a cnidoblast cell. Also draw a nematocyst in the process of being discharged from its cell, if such an example appears on your prepared slide.

Resources

Carolina Biological. *Hydra Life Cycle*. #52-4212, 1 filmstrip and cassette.

Educational Images, Ltd. *Coral Reefs and Their Residents*. #C 3007, computer program, Apple.

Kerstich, Alex. *The Biology of Coral Reefs*. FS 1024, 2 filmstrips, cassettes, and guide, available from Educational Images, Ltd.

Kohl, Larry. "British Columbia's Cold Emerald Sea," *National Geographic*, April 1980.

Marine-Land, Inc. "Jellyfish and Their Relatives." #05281-910, video; available from Center for Humanities, Inc.

Shinek, Ronald L. "Sex Among the Sessile," *Natural History*, March 1987.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

alternation of generations
basal disc
Coelenterata
Ctenophora
Hydra
medusa
nematocyst
polyp

Review

28. Hydra

Name______________________________

Date______________________________

Multiple choice

______ 1. Which of the following is not characteristic of the medusa body type?
a. umbrella-shaped
b. sexual stage
c. mouth on concave side
d. sessile

______ 2. The type of symmetry exhibited by the coelenterates and some of the poriferans is
a. circular
b. linear
c. radial
d. bilateral

______ 3. Both the coelenterates and the poriferans have the ability to grow back lost parts. This is due to the limited specialization of their cells and is known as
a. reincarnation
b. reconstitution
c. rejuvenation
d. regeneration

______ 4. Of the following animals, the one that has a medusa body type is the
a. coral
b. Portuguese Man 'O War
c. anemone
d. jellyfish

______ 5. The class of *Coelenterata* which includes the *Hydra* is the
a. *Hydrazoa*
b. *Sporozoa*
c. *Scyphozoa*
d. *Anthozoa*

True or False

______ 6. The body wall of the *Hydra* consists of three tissue layers.

______ 7. *Hydra* have a primitive nervous system.

______ 8. Sexual reproduction does not occur in the *Anthozoa*.

______ 9. Concerning the alternation of generations of the coelenterate *Hydra*, the diploid stage is the polyp, and the haploid stage is the medusa.

______ 10. In food getting, the nematocysts and tentacles of the *Hydra* always work together to move prey to the mouth.

______ 11. The actual stinging structure of the *Hydra* is called a trichocyst.

______ 12. *Ctenophora* are commonly known as the combed jellies.

______ 13. A sea anemone has a medusoid body plan.

______ 14. A *Hydra* has a polyp body plan.

______ 15. The *Hydra* is carnivorous.

29. Laboratory

Planaria

When you have completed this laboratory you should be able to:

1. Understand the structure and life cycle of flatworms.
2. Observe the reaction of planaria to various stimuli.

Phylum *Platyhelminthes*

The phylum *Platyhelminthes* is commonly known as the flatworms. They are the simplest animal phylum with a distinct head and developed organ systems. They exhibit bilateral symmetry, that is, the two sides of the organism are mirror images of each other. They have three cell layers, as compared to the two layers of sponges and jellyfish. The inner layer has developed into specialized endodermal tissue constituting a gastrodermis, and the middle layer, the mesodermis, has developed into layers of muscle, connective tissues, and reproductive organs. Neither a true coelom (body cavity) nor a circulatory system is present.

The flatworms have a single opening to the gut which functions as both a mouth and an anus. Therefore, like the coelenterates, they ingest and egest solid material through the same opening. However, some flatworms have developed a complete system for fluid excretion, unlike the sponges and coelenterates whose individual cells excrete waste fluids by simple diffusion into the environment. Free-living flatworms have well developed excretory systems with many branched tubules, excretory pores on the body, and specialized cells called flame cells which withdraw fluid from surrounding tubules for excretion. Cilia move the excess water toward the excretory pores.

Members of the phylum *Platyhelminthes* have a central nervous system with a simple brain, two ventral longitudinal nerve cords, as well as transverse nerves. These animals possess a simple memory and are trainable. The ladder-like nervous system of one order of flatworms, as well as the excretory, digestive, and reproductive systems, are illustrated in figure one.

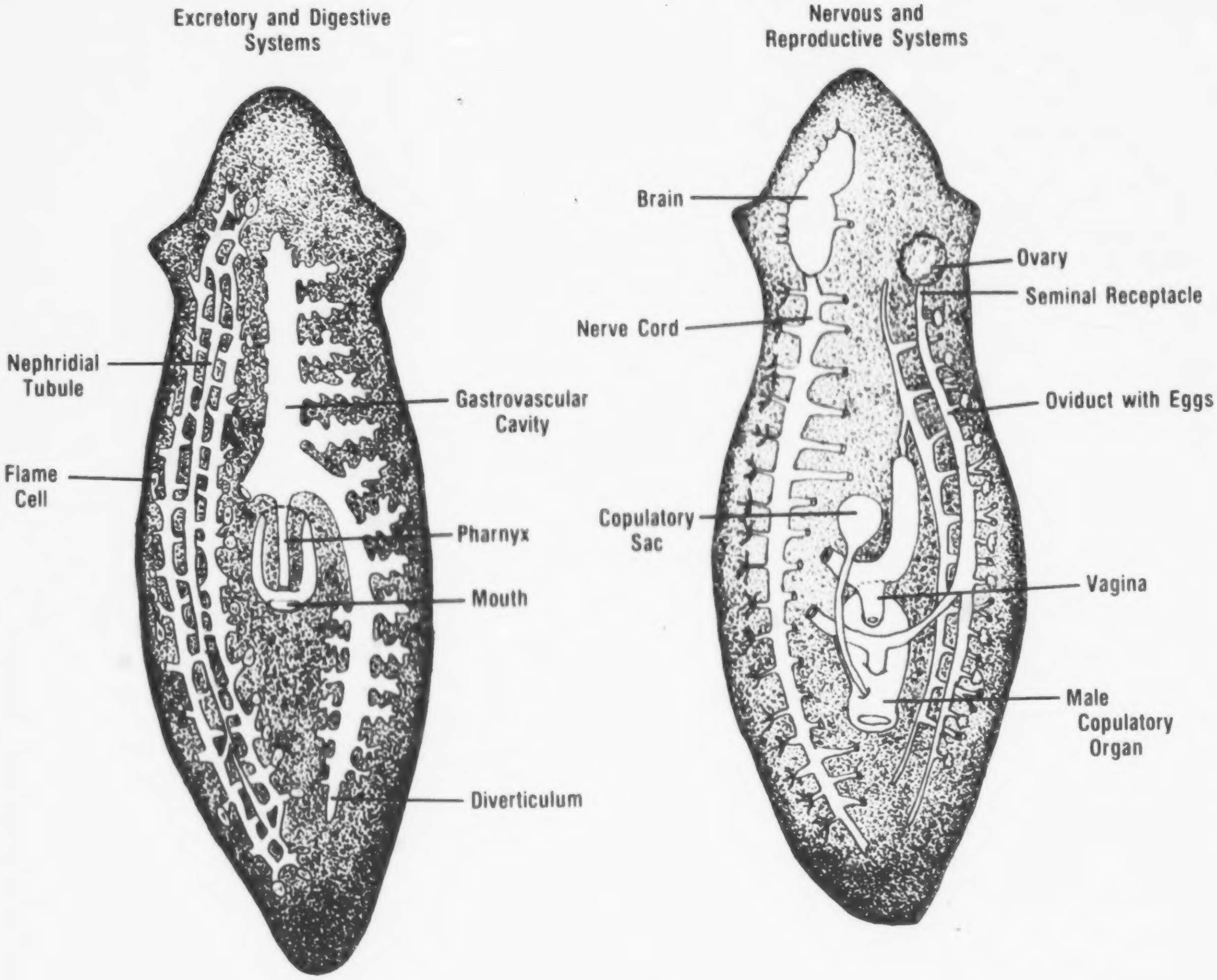
Turbellaria

Flatworms are divided into three classes based upon their structure and life history. The class *Turbellaria* contains all the free-living flatworms. A major groups within this class are the planaria, one member of which, *Dugesia*, will be discussed and studied later in this laboratory. The other two classes of flatworms contain only parasitic organisms.

Trematoda

The class *Trematoda* contains the flukes. Flukes attach to the host by means of suckers, and the entire adult epidermis is replaced by a cuticle so that the host cannot digest the fluke. Most flukes are ectoparasites, that is, they parasitize by attaching to the outside of an organism by suckers.

Several families of *Trematoda* attach to vertebrate internal organs, such as the intestines, or float in the bloodstream. Bilharzia, a liver fluke disease which is the scourge of the Nile River Valley, has now spread to more than seventy-one countries, afflicting, it is estimated, up to 300 million people. The Bilharzia liver fluke has as its alternate host fresh water snails, and people are infected by free-swimming larvae which attach to the skin and penetrate to the blood stream (swimming in the Nile is not recommended). Eggs are returned to the water and the intermediate host by both feces and urine. A cure for this debilitating disease has still to be found.


Excretory and Digestive Systems
Nephridial Tubule
Flame Cell
Gastrovascular Cavity
Pharnyx
Mouth
Diverticulum
Nervous and Reproductive Systems
Brain
Nerve Cord
Copulatory Sac
Ovary
Seminal Receptacle
Oviduct with Eggs
Vagina
Male Copulatory Organ

Planaria

Figure 1

Cestoda

The class *Cestoda* includes all the tapeworms. They are endoparasites, that is, they live a parasitic life inside a host. The tapeworm has lost its mouth and digestive tract, because it is able to digest food directly through the cuticle by simple diffusion. The head area is developed into a scolex, or knob-like structure armed with hooks or suckers by which the animal attaches itself to the host, usually in the digestive tract. The scolex also contains the brain of the animal. Tapeworms are segmented, being built of units called proglottids which add on from the neck down as the animal grows. Some tapeworms can grow to five or six meters in length, and, along with weakening a host through parasitism, they can block the intestinal track because of their considerable size. Each proglottid contains a complete set of reproductive structures which function as soon as the proglottid reaches maturity.

Most tapeworms have a life cycle involving more than one host. A common human tapeworm, the beef tapeworm, infects those who eat undercooked meat from cattle which have grazed on land contaminated by feces. Tapeworm eggs, millions being produced by every adult tapeworm, pass out of the host's body with the feces, and the eggs lie in the soil until eaten by the next host.

Planaria

Members of the turbellarian order *Planaria* are abundant in freshwater streams and ponds around the world. They can be found on the under or shaded side of submerged objects where they live a carnivorous life. They look somewhat like small blobs of gray, brown, or white jelly. They can be collected by tying a piece of liver to a string and letting the liver lie on the bottom of a quiet stream or pond for a few hours.

Members of the genus *Dugesia* are about two centimeters long and have a triangular head with two lateral lobes known as auricles. The auricles contain olfactory organs. They also have eyespots on the dorsal side of the head. On the ventral side of the animal, about one-third of the way toward the tail, lie the mouth and pharynx. A genital pore is posterior to the mouth on the ventral side.

Planaria move in two ways. The usual way is by gliding, with the head slightly raised, over a slime track that they secrete. They move in the track by beating epidermal cilia. The less common way of moving is by crawling. The worm lengthens, anchors its anterior end with mucous, and then contracts to bring the rest of its body forward.

The digestive system consists of a mouth, pharynx, and intestine. Planaria are mainly carnivores, feeding upon injured or dead prey. They have chemoreceptors in their auricles and can detect food for some distance. They capture small organisms by entangling them in mucous secretions (this gives new meaning to the ghostbusting term "slimed to death"). Planaria hover over food, and extend their pharnyx, like a straw, into it, sucking up small bits of food which already have been partially digested by extracellular enzymes secreted by the planaria. Food is more completely digested once it enters an animal's digestive tract. Since the digestive tract dead ends, in a structure called a diverticulum, all undigested food must be egested.

Planaria reproduce both asexually and sexually. Asexually they can regenerate in a fashion similar to both sponges and coelenterates. They also divide transversely by simple fission. Sexually, planaria are hermaphrodites, that is, they possess both male and female reproductive structures. However, these structures are only visible certain times of the year, and even then they are difficult to see.

During this laboratory you will study the external structure of a live planaria and then observe its reaction to various stimuli. You also will study a prepared slide which contains a whole mount section of a planaria with a stained digestive tract.

Pre-lab

Supplies needed:

Equipment

dissecting scope or hand lens
penlight flashlight
eye dropper

microscope
watch glass
probe

prepared slide, whole mount planaria with stained digestive tract

Materials

live *Dugesia*

vinegar

liver

Special Preparations

1) Aerate (see laboratory twenty-six) planaria upon receipt, and place in a cupboard until class.

2) One chicken liver will provide more than enough liver for two classes. The liver should be fresh for best results.

3) Dilute the vinegar 50% with water. 5 ml. should be sufficient for one class.

Time Required

The planaria laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Using an eye dropper, carefully transfer a planaria, along with enough culture water to cover the animal, to a watch glass. Study the animal using a dissecting scope with as little light as possible. Allow the animal a few minutes to adjust to this new environment. As it adjusts, you will see changes in its behavior.

Identify the following external features. You may need to carefully, with as little disturbance as possible, hold the watch glass in the air in order to look at the underside of the animal.

- Body shape and length.
- Head.
- Auricles and eyespots: on the dorsal side of the head.
- Mouth and pharynx: on the ventral side of the animal, approximately one-third of the way down the body from the head.

1. How long is your animal? Also describe its color.

2. In what body position was the planaria when you first observed it?

3. After approximately five minutes, what is the animal doing?

4. Describe the way the animal moves.

B. You now will perform a series of steps testing planarian responses.

Create a current in the water by using your eye dropper.

5. How does the animal react to a water current?

6. Consider where planaria live. How does your animal's reaction to a water current aid in its survival?

Gently touch the auricles with your probe.

7. How does the animal react? ______________________________

____

____

Touch other areas of the animal's body with your probe.

8. How does the animal react? ______________________________

____

____

Shine a light on the eyspots.

9. How does the animal react? ______________________________

____

____

Shine the light on the posterior end of the animal's body.

10. How does the animal react? ______________________________

____

____

____

C. Put a tiny piece of liver in the water near your animal. Make sure that the liver is no larger than one-fourth the size of your planaria. Allow the animal a few minutes to adjust to this new situation. As it adjusts, you will see changes in its behavior.

11. What is the animal's reaction to the liver? Describe its actions. ______________________________

____

____

____

____

D. Add a drop of dilute vinegar to the water in your watch glass.

12. How does the planaria react? ______________________________

____

____

____

E. Dispose of your study materials by returning the planaria to the class culture dish and pouring the vinegar contaminated culture water down a drain.

F. Using a microscope, study a prepared whole mount slide of a planaria with a stained digestive system. Study the slide under both low and high power objectives.

13. In the space provided below, draw the digestive system of a planaria. Label all visible structures.

Resources

Belinky, Charles R. and Jan L. Wassink. "Sponges, Anemones, Corals, and Flatworms." *Survey of the Animal Kingdom: The Invertebrates.* #FS 1058, one part of a four part filmstrip series with cassettes and guides. Educational Images, Ltd.

Wards Biology. *Cestodes.* #170-W 8600, 17 slides

Wards Biology. *Parasitology and Tropical Medicine.* #173-W 0632, 100 slides and guide.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

auricle
bilateral symmetry
ectoparasite
endoparasite
eyespot
diverticulum
fluke
mesodermis
pharynx
Planaria
Platyhelminthes
proglottid
scolex
tapeworm

Review

29. Planaria

Name ______________________________

Date ______________________________

Multiple choice

______ 1. Which of the following types of worms is not a parasite?
a. planaria
b. fluke
c. tapeworm
d. hookworm

______ 2. Which of the following types of symmetry is characteristic of flatworms?
a. radial
b. biradial
c. lateral
d. bilateral

______ 3. The first animal phylum to possess a distinct head with sense organs is the
a. *Porifera*
b. *Platyhelminthes*
c. *Coelenterata*
d. *Nemathelminthes*

______ 4. The segments in a tapeworm are called
a. somites
b. glottis
c. proglottids
d. scolex

______ 5. Free-living carnivorous flatworms are grouped in which of the following classes?
a. *Turbellaria*
b. *Trematoda*
c. *Cestoda*
d. *Planaria*

______ 6. If you wanted to destroy the chemoreceptors of a planaria, you would remove its
a. eyespots
b. pharynx
c. auricles
d. gizzard

______ 7. Which of the following animals is the lowest form to show any capacity for learning?
a. Sponge
b. *Ascaris*
c. *Planaria*
d. *Hydra*

______ 8. *Planaria* is
a. bisexual
b. asexual only
c. homosexual
d. hermaphroditic

______ 9. Most of the *Cestoda* are
a. endoparasites
b. ectoparasites
c. free-living
d. saprophytes

______ 10. The digestive tract of a *Planaria* ends in a(an)
a. anus
b. coelom
c. rectum
d. diverticulum

Essay

1. Describe the characteristics of the three classes of flatworms.

2. What additional specialization is possible in animals with three cell layers as compared with those having only two?

30. Laboratory

Ascaris

When you have completed this laboratory you should be able to:

1. Understand the structure and life cycle of unsegmented roundworms.
2. Trace the digestive and reproductive organs of *Ascaris*.

Phylum *Nemathelminthes*

The phylum *Nemathelminthes* contains the unsegmented roundworms. These worms are found in every conceivable habitat in the world, some being free-living, some parasitic, and some living in plants and animals without causing significant damage to their host. The *Nemathelminthes* range in size from microscopic to more than a meter in length. Like the *Platyhelminthes*, the unsegmented roundworms have three tissue layers, bilateral symmetry, and well developed organ systems. However, they do differ, in that they are the simplest animals with a cylindrical, or round body, a digestive tract with two terminal openings (both a mouth and an anus), and the presence of a body cavity, called a pseudocoelom.

Class *Nematoda*

Experts disagree over placement of organisms in the phylum *Nemathelminthes*, with some arguing that particular classes warrant a separate phylum. For simplicity, you will consider in this laboratory only the class *Nematoda* as being representative of the complete phylum. The *Nematoda* are commonly called roundworms, and to date more than 12,000 species have been identified. Most roundworms are free-living, microscopic animals, and they are widely spread. You can collect an estimated million nematodes every time you dig a shovel full of dirt. They have a thick cuticle covering their bodies and only longitudinal muscles. Therefore, they can thrash back and forth, but they cannot move forwards or backwards.

Some members of the *Nematoda* are parasitic. It is estimated that fully one third of the human population is infected with roundworm parasites at any one time. Examples are the hookworm, trichina worm, pinworm, whipworm, *Ascaris*, *Filaria*, *Onchocerca*, and the guinea worm.

Hookworms

Hookworms are bloodsucking intestinal nematodes which sap the vitality of the host. More than 450 million people are estimated to be infected with hookworms. Hookworms are one-host parasites, and their eggs pass out of the body with feces to hatch in the soil. The free-living larvae remain in soil until they make contact with a host. They then bore through the skin into the bloodstream. The disease is spread through a combination of improper sewage disposal, warm soil conditions, and bare feet. Hookworms are common in the Southeastern United States.

Pinworms and Whipworms

Pinworms and whipworms have life cycles similar to the hookworm, but they usually gain entry through a body opening, such as the mouth. Children playing in contaminated dirt or a sandbox are at risk. Pinworms, the more common of the two, lay their eggs near the anus, and this can produce inflamation and itching in that area. Sometimes their presence can be detected by placing a piece of scotch tape over the anus early in the morning. White eggs or small whitish worms stuck to the tape reveal the presence of the parasite in the individual's body. Pinworms are an extremely common parasite.

Trichina worms

Trichina worms cause trichinosis which can be fatal. They are transmitted to humans who eat undercooked pork. In a host, such as a pig, dog, rat, or cat, larvae are distributed throughout the body via the bloodstream, and they burrow into striated muscles. The worms encyst in the muscles and may stay in that state for several years. When another host, such as a man, eats infected meat, the worm cysts dissolve during digestion and in about four days mature in the new host's intestine. The trichina worms then burrow into the intestinal wall, causing diarrhea, pain and fever.

The female worm releases eggs into the intestinal tissues. The resulting larvae move to the bloodstream, and the cycle repeats. The host suffers intense muscular pain, movement problems, and sometimes death during the phase when larvae are burrowing into muscle. Unlike many parasitic infestations, trichinosis is most common in temperate, not tropical, areas.

Tropical Worms

Guinea worms are found only in tropical countries. They live in the tissue immediately underneath the skin, unlike intestine-dwelling pinworms and whipworms. They can grow to more than one meter in length and, because of size, can cause abscesses on the skin. Guinea worms can be removed by cutting open an infected area and gradually pulling out the entire worm.

Filaria worms cause filariasis, also known as elephantiasis, throughout tropical regions. This parasite also has been reported in the Southeastern United States. *Onchocerca* worms cause "river blindness" or loa loa, and it is closely related to *Filaria*. River blindness occurs in the fertile regions of West Africa and in the coffee growing areas of Mexico and Guatemala. These plagues are spread by the bites of infected insects, such as mosquitos and flies, and a simple cure for them has yet to be found.

Ascaris

Ascaris lumbricoides, an intestinal roundworm, is one of the most common human parasites. Fortunately, its impact is rarely fatal. It is estimated that more than 650 million people harbor *Ascaris*. Infection normally results from swallowing worm embryos with contaminated food or water. *Ascaris* also infect pigs and other vertebrates, although it reproduces only in man. The embryos are resistant to digestion because of tough cuticles. They hatch in the upper intestine and quickly burrow into the intestinal wall where they enter the capillaries or lymphatic system, pass through the heart, and then circulate throughout the body. They eventually reach the tissues of the lungs where they attach themselves for about ten days of a new phase in their life cycle. They then bore into the bronchial tubes and ascend into the mouth, where they are swallowed and thus regain entrance to the intestines. Infected people may notice some congestion or even see tiny white worms in their sputum or nasal mucous.

The worms grow to adulthood during their second period in the intestines when they feed on intestinal contents and mate. Once mature, the reproductive system of the female contains millions of eggs, and she can lay as many as 200,000 eggs every twenty-four hours. The eggs pass out of the host's body with feces. The eggs can remain alive in soil for months. Under favorable conditions of moisture and warmth, they develop into embryos, and the cycle repeats.

Ascaris Structure

Mature female *Ascaris* worms are between twenty and thirty centimeters long, while the males range between fifteen and twenty centimeters in length. The male is easily distinguished from the female both by its smaller size and by the presence of two large penial spicules on its anus. These worms, like other *Nematoda*, have no special organs for respiration or circulation.

Study the figure one diagram for Ascaris structure. As in most parasites, the main body components are the digestive tract and the reproductive tract. In a female *Ascaris*, the ovaries may coil in and around the pseudocoel area, somewhat like spaghetti, and cover other internal organs in the process.

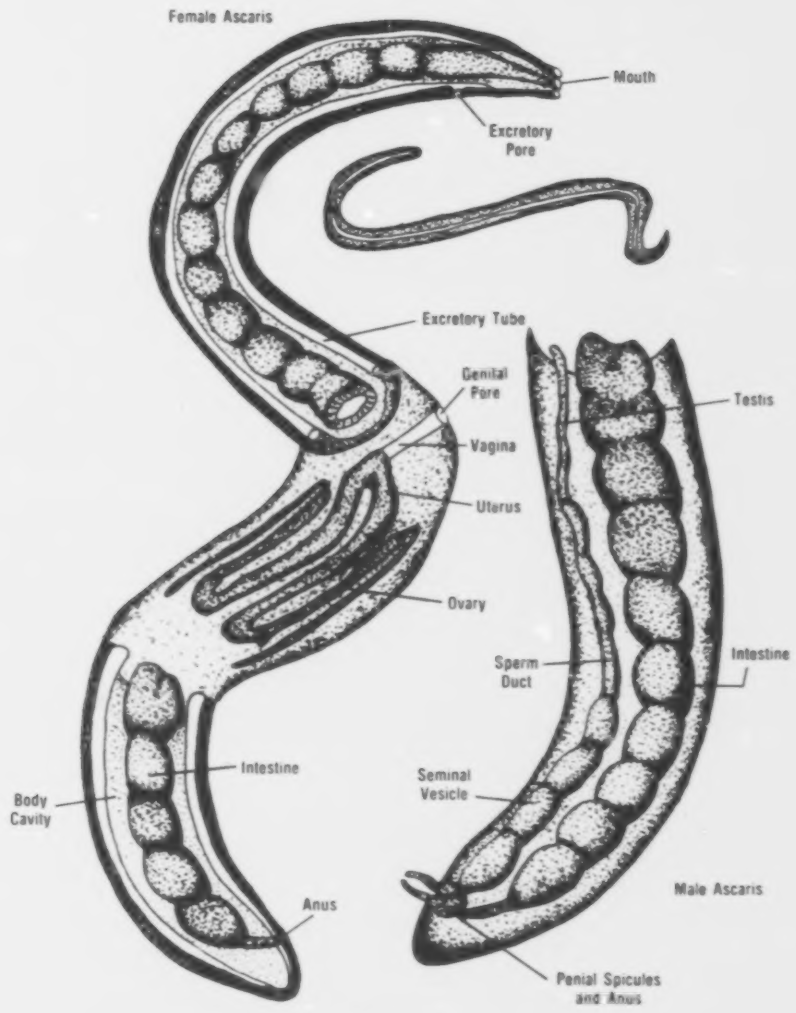

Female Ascaris
Mouth
Excretory Pore
Excretory Tube
Genital Pore
Vagina
Uterus
Ovary
Testis
Sperm Duct
Intestine
Intestine
Seminal Vesicle
Body Cavity
Anus
Male Ascaris
Penial Spicules and Anus

Figure 1

In this laboratory you will dissect an *Ascaris* worm, studying in particular its digestive and reproductive systems.

Pre-lab

Supplies needed:

Equipment

dissecting pan
probe
scissors
pins
razor blade.

Materials

1 preserved *Ascaris* worm

Special Preparations

None.

Time Required

The *Ascaris* laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Place your specimen in a dissecting pan, and identify the following external features.

- Cutícle.
- Mouth and prostomium: the prostomium is a type of lip which overhangs the mouth. In *Ascaris* the prostomium appears to be in three parts.
- Excretory pore: on the ventral surface, just behind the mouth region.
- Sex parts: in the male, the post anal region, or tail, is sharply curved down, while the contour of the female tail is a straight tube. Also, the male has visible penial spicules in the anal region.
- Anus.
- Longitudinal lines: there are four, dorsal, ventral, and two thicker, brownish lateral lines.

1. Diagram your worm and label all external features in the space provided below. Note the sex of your worm.

B. Make a slit along the mid-dorsal line from the anterior to the posterior end. Do **not** cut too deeply. Spread and pin the open flaps of surface tissue to the pan so that the internal organs can be seen. Gently cover the worm with water (which helps support delicate structures which might otherwise break during dissection). Identify the following:

- Esophagus: very muscular.
- Intestine: note the thin walls.
- Rectum.

2. Diagram the digestive system of your worm, and label all features in the space provided below.

C. Continue your study of internal structures by identifying parts of the reproductive system.

If your worm is a male,

- Penial spicules: used to attach to a female during copulation.
- Ejaculatory tube: for the discharge of sperm.
- Seminal vesicle: for the storage of sperm.
- Vas deferens: for sperm conduction.
- Testis: coiled structures which produce sperm.

If your worm is a female,

- Genital pore.
- Vagina.
- Uterus: these are two horn-like structures extending from the vagina.
- Oviducts: one extending from each uterus, for egg conduction.
- Ovaries: for egg production.

3. Diagram the reproductive system of your worm, and label all structures in the space provided below.

4. Does *Ascaris* have respiratory and circulatory systems? Why or why not? ____________________

____

____

____

5. How are the systems of *Ascaris* modified for a parasitic life style? ____________________

____

____

____

____

____

____

6. Complete the review chart, figure two below, by filling all squares with key words. "First to Have" line asks for the simplest animal which possesses a particular structure or function.

	Sponge	Hydra	Planaria	Ascaris
Phylum				
Class				
Genus				
Symmetry				
Locomotion				
Life Style				
Cell Layers				
Habitat				
Digestion				
Excretion				
Respiration				
Nervous System				
Asexual Reproduction				
Sexual Reproduction				
First to Have				
Related Animals				

Figure 2

Resources

Apple. *Hookworm Life Cycle.* #74 W 3013, computer disk with user's and program guide available from Ward's.

Educational Images. "The Invertebrates," *Survey of the Animal Kingdom.* #70 W 3096, 4 filmstrips and cassettes available from Ward's.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- *Ascaris*
- hookworm
- *Nemathelminthes*
- *Nematoda*
- pinworm
- pseudocoelom
- trichina worm

Review

30. *Ascaris*

Name ______________________________

Date ______________________________

Multiple choice

______ 1. Which of the following types of symmetry is charactistic of the flatworms and roundworms?
a. spherical
b. radial
c. lateral
d. bilateral

______ 2. Which of the following worm types is found in nearly every habitat?
a. *Cestoda*
b. *Nematoda*
c. *Trematoda*
d. *Turbitoda*

______ 3. The trichina worm spends part of its life cycle in a
a. snail
b. mosquito
c. pig
d. fish

______ 4. It is essential that an intestinal parasite have
a. an efficient digestive system
b. a thick, resistant cuticle
c. circular and longitudinal muscles
d. a complex nervous system

______ 5. *Nematoda* are more advanced than *Platyhelminthes* because they possess
a. no method of asexual reproduction
b. a mouth and an anus
c. a pseudocoelom
d. all of the above

______ 6. The body cavity of an animal is a
a. mesoderm
b. coelom
c. gemmule
d. trochophore

______ 7. A parasite that can be contracted by going barefoot in worm-invested soil is the
a. leech
b. trichina worm
c. hookworm
d. tapeworm

______ 8. The vas deferens in the *Ascaris* is used for
a. sperm production
b. sperm conduction
c. temporary sperm storage
d. sperm discharge

______ 9. Which of the following is true of the *Nematoda*? They are the simplest animals to
a. have an anus and a mouth
b. exhibit radial symmetry
c. have a true respiratory system
d. have a true circulatory system

______ 10. Which of the following is **not** a difference between the male and female *Ascaris*?
a. male has a curved posterior end
b. female is generally longer
c. male is usually thicker or fatter
d. female has an oviduct

True or false

_______ 11. Fertilization in *Ascaris* is internal.

_______ 12. *Ascaris* possess no true structures for circulation and respiration.

_______ 13. *Ascaris* are monoecious.

_______ 14. *Ascaris* can thrash about by alternate contractions of circular muscles.

_______ 15. The hookworm is common in the Southeastern United States.

_______ 16. The pinworm is found only in the slow moving rivers of the tropics.

_______ 17. The alternate host of *Filaria* is an insect.

_______ 18. The alternate host of hookworm is the pig.

_______ 19. Most *Nematoda* are free-living.

_______ 20. *Ascaris* excrete via an excretory pore.

31. Laboratory

Earthworms

When you have completed this laboratory you should be able to:

1. Understand the structure and life cycle of segmented roundworms.
2. Observe the reaction of earthworms to various stimuli.

Phylum *Annelida*

Annelids are segmented worms. Their body wall and coelom, or body cavity, are divided into a longitudinal series of rings or segments. Some simpler animals, such as tapeworms, have structures that look somewhat like segments, but each segment of a tapeworm is eventually shed. Therefore, it is only a temporary part of a tapeworm body. True segmented animals, such as *Annelida*, are permanently segmented, and that segmentation involves a repetition of certain structures or organs from segment to segment. This repetition is called metamerism, and the segments of such animals are referred to as metameres (or, by some, as somites).

Annelids possess a complex external and internal organization. For example, all annelids have a mouth located between the first and second segments. The mouth is overhung by a prostomium, or worm lip. All annelids have a thin cuticle secreted by a simple epidermis. Each segment of the body has a ring of circular muscle fibers which can constrict and thereby elongate the segment. Beneath the circular muscles are several bands of longitudinal muscles that can produce body shortening and thickening. The coelom, which divides the epidermis from the digestive tract, is divided by thin muscular septa, or separations.

Classification

There are four classes of *Annelida*. The class *Polychaeta*, which means "many bristles," is composed chiefly of marine animals with eyes, tentacles, and appendages called parapodia. The parapodia are flaps of skin, with bristles called setae, attached to each body segment. *Polychaeta* sexes are separate and fertilization is external. Their eggs develop into larvae called trocophores which form an important part of the ocean plankton. The trocophores eventually metamorphose into worms and sink to the ocean floor.

The class *Hirudinea* includes both freshwater and terrestrial leeches. They have one large sucker surrounding the mouth and another at the posterior end of the body. They are either carnivorous or bloodsucking parasites. They have no setae.

The class *Archiannelida* consists of a few marine animals which are very small and reduced in complexity, that is, they show relationship to the other *Annelida* but have lost many of the special characteristics of the phylum, such as external segmentation and setae.

The Class *Oligochaeta*

Oligochaetes are freshwasher or terrestrial annelids. They have setae but lack eyes. All oligochaetes are hermaphroditic, and fertilization is internal. The eggs are heavily yolked, and thus they can hatch directly into little worms, without having to go through a larval feeding stage. This class contains the economically important species called earthworms. Terrestrial worms burrow and live underground, eating their way through the world's organic debris. They have external structures specialized for burrowing. Aquatic oligochaetes have the same life-style, but they live in mud.

Earthworms

Earthworms break-up, enrich, and aerate the soil. Charles Darwin, in his study of earthworms, *The Formation of Vegetable Mould through the Action of Earthworms*, estimated that in his area of England fifteen tons of castings (earthworm feces) are deposited annually on each acre of land, perhaps twenty ounces per worm per year. These are impressive manure figures. Can you determine how many earthworms per acre of land would be necessary to arrive at Darwin's estimate of castings? Such huge numbers of earthworms are critical to soil fertility and friability throughout the world.

During this laboratory you will study a live earthworm and become acquainted with its external structures and how it responds to changing environmental conditions. You also will dissect an earthworm and identify its internal structures. (Most often earthworms available for observation and dissection are *Lumbricus terrestris*, the garden earthworm).

Pre-lab

Supplies needed:

Equipment

dissecting scope or hand lens
T-pins
scissors
forceps
dissecting pan
2 probes
razor
paper towels

Materials

live earthworm
preserved earthworm

Special Preparations

1) Live earthworms are obtainable from local earthworm farms, stores catering to fishermen, biological supply houses, or directly from local soil, if the season is right. If you obtain the worms in advance, leave them in moist soil in the refrigerator for up to two weeks, or until it is time for the laboratory session.

2) It is best to obtain preserved earthworms from biological supply houses. Although you can preserve earthworms for dissection, the materials used commercially harden the internal organs, making it easier for students to identify these structures.

Time Required

The earthworms laboratory requires one and a half classroom hours, in addition to preparations, discussion, and review.

Procedure: Partial Hour 1

Students need the following: dissecting pan, paper towels, live earthworm, and dissecting scope or hand lens.

Steps

A. Place your live earthworm on a damp paper towel in a dissecting pan. Study the worm, and identify the following external structures:

- Dorsal (top) and ventral (bottom) sides of the worm.
- Anterior (front) and posterior (hind) ends.
- Mouth (at the anterior end) and anus (at the posterior end).
- Segments.
- Clitellum: a girdle-like structure that encircles the worm.
- Setae: earthworm bristles which can be felt if you run your fingers from the tail of the worm to the head, but not if you run your fingers in the opposite direction.

1. Is the dorsal or ventral side darker in color?

2. This color difference is due to the presence of a blood vessel running the length of the worm's body. Can you hypothesize as to how this difference in color might be advantageous to the earthworm? Explain.

3. Describe how the worm behaves when you handle it.

4. How does it behave when you leave it undisturbed?

B. Fold a piece of damp towel over the posterior end of your worm. Study its behavior when the towel is placed on top of it.

5. How does the towel change the worm's behavior?

6. Describe how the worm moves.

7. How does the worm move backward?

8. Locate the setae on your worm. Where are they?

9. How many setae are on each segment? Are they on every segment?

10. How are the setae used in locomotion? ______

______

______

11. Locate a girdle-like structure encircling your worm. This is the clitellum. How many segments does the clitellum cover?

______

Procedure: Hour 2

Students need all listed supplies, except for the live earthworm.

Steps

A. Place a preserved earthworm, dorsal side up, in your dissecting pan. Pin both ends of the worm to the wax at the bottom of the pan. Begin cutting, through the body wall **only**, about two centimeters behind the clitellum, and cut forward through the body wall slightly to the left of the dorsal blood vesel. Continue the cut to the prostomium. Separate the edges of the cut so that the coelomic cavity is visible. Observe the septa, or divisions, extending from the body wall to the intestine. Break the septa, using your forceps and probe. Pin the sides of the body wall to the wax, so that the internal structures are completely exposed. ,

B. Identify the following internal structures, using the figure one diagram as a guide.

- Mouth, buccal cavity, pharynx, esophagus, crop, gizzard, intestine, and anus: these constitute the digestive tract and are listed in order. On the esophagus you might be able to see small white round glands, called calciferous glands. These glands secrete calcium into the esophagus to neutralize acid. If the earthworms were taken from acidic soil, these glands will be obvious; if they were taken from neutral or basic soil, they will be difficult to spot.
- Seminal vesicles, seminal receptacles, and ovary: the vesicles store sperm until copulation occurs and are found on segments ten, eleven, and twelve, and their external opening is found on segment fifteen. The receptacles are on segments nine and ten, and they receive sperm from another worm through the receptacle openings located on these same segments. The ovary is underneath the vesicles, but it is very difficult to find. You might see the oviduct opening on segment fourteen.
- Dorsal blood vessel and aortic arches: the dorsal blood vessel lies above the digestive tract, and the arches lie over the esophagus region. There also is a ventral vessel which lies between the intestine and nerve cord, but it is very difficult to see.
- Nephridia: small white, loose tubes along each side of the digestive tract. You will need to use the dissecting scope to locate these tiny structures. Nephridiopores, or nephridial openings, are paired excretory openings located on the lateral ventral side of each segment, except for the first three and the last.
- Brain and ventral nerve cord: the "brain" (the group of two nerve cords) is dorsal to the buccal cavity. The two nerve cords pass around either side of the esophagus to join below the esophagus and form the ventral nerve cord.

12. Identify the circular muscles. How does the animal change shape when these muscles contract? ______

______

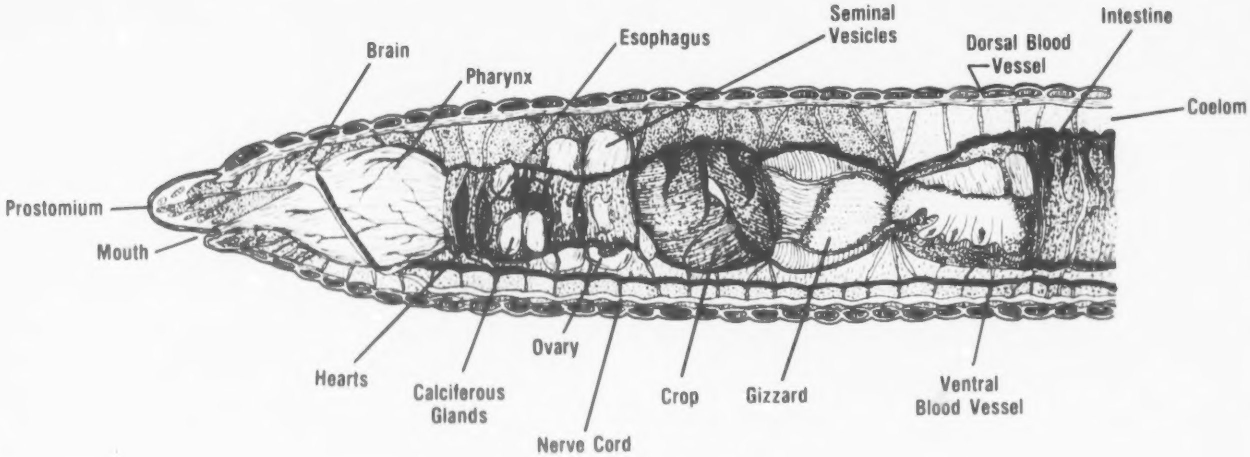
______

______

13. Identify the longitudinal muscles. How does the animal change shape when these muscles contract?

______

______


Brain
Pharynx
Esophagus
Seminal Vesicles
Dorsal Blood Vessel
Intestine
Coelom
Prostomium
Mouth
Hearts
Calciferous Glands
Ovary
Nerve Cord
Crop
Gizzard
Ventral Blood Vessel

Internal Structures of the Earthworm

Figure 1

14. Identify the structures of the digestive tract. For each structure, determine the number of the segment it lies within. For example, the mouth is on the first segment, and the buccal cavity passes from the mouth to the third segment. Write the segment number for listed structures in the chart, figure two, provided below.

Structure	Segment #	Structure	Segment #
mouth		crop	
buccal cavity		gizzard	
pharynx		intestine	
esophagus		anus	

Figure 2

15. Compare your segment numbers with your classmates. Are the segment numbers for these structures always the same? Why or why not?

16. How large are the calciferous glands of your specimen in comparison with the esophagus, and how many can you find?

17. How are the calciferous glands of an earthworm of advantage to a farmer? ____________________

____

____

C. Remove a section of the intestine by making two cross-cuts in the intestine approximately one centimeter apart. Carefully clean away any debris which might be inside the intestine. Study the cross-cut section with the aid of a dissecting scope or hand lens. Instead of a simple cylindrical intestine, as you found in *Ascaris*, the earthworm has a more advanced intestine called a typhlosole intestine.

18. Diagram a cross section of the typhlosole intestine in the space provided below.

19. The structure of a typhlosole intestine provides more surface area for contact with food inside the intestine. How might this increased surface area be an advance in worm digestive capability?

____

____

____

____

20. Identify the seminal vesicles, receptacle, ovary, and their external openings. Why is the earthworm called a hermaphrodite?

____

____

____

Earthworms reproduce in any season, but it is most common during the spring when the weather turns warm and moist. They copulate tail to end, and this body arrangement places the seminal receptacle openings of one worm in contact with the clitellum of the other worm. Segment fifteen of each worm makes contact with segment twenty-six of the other. Mucous secretions and setae hold the worms together during copulation, which takes about two hours. Later, each worm will secrete a barrel-shaped cocoon about its clitellum. Eggs from the oviducts are passed to the cocoon, and the worm backs out of the cocoon. As the worm backs out, sperm stored from copulation spills out into the cocoon. Fertilization takes place within the cocoon.

21. Diagram, in the space provided on the next page, how the reproductive structures of two earthworms fit together during copulation. Number the segments involved in this process, as shown on your diagram, and also label the external structures and openings you depict.

D. Identify the dorsal blood vessel and aortic arches.

The aortic arches serve as the earthworm's heart, in that they pump blood throughout the body. Although not as large or specialized as the aortic arches, there are similar structures in every segment of the animal's body; these, however, are difficult to see during a simple dissection. The dorsal blood vessel conveys blood forward in the animal; it contains valves which prevent reverse blood flow. There also is a ventral vessel which lies between the intestine and nerve cord. This too is very difficult to identify during dissection. The ventral vessel receives blood from the arches and carries it anteriorly to the brain area and posteriorly to the tail region.

22. How many arches are there? What segments do they lie within? ______________________________

____

____

23. Why is it said that the earthworm has a closed circulatory system? ______________________________

____

____

24. Trace the flow of blood in an earthworm from the arches and back again. ______________________

____

____

____

____

____

E. Identify the nephridia, which constitute the excretory organs of your specimen. To see these structures, extend your initial cut into the worm about five centimeters further toward the tail from the clitellum. Pin back the body wall, and gently pull out the intestine. Cut about an eight centimeter section of intestine out of the body, and study it with the aid of a dissecting scope or hand lens. Use a probe to manipulate the intestinal wall.

25. How many nephridia are present in an earthworm segment? ______________________________

F. Identify the brain and ventral nerve cord. You can see the ventral nerve cord where you removed part of the intestinal tract of the animal, since the ventral nerve cord lies underneath the intestine. Cut the nerve cord and pull it free of the body. Notice the small nerve branches.

26. Where do these small nerves go?

27. The brain lies within what segments of the earthworm?

Notice that the earthworm does not have structures for a respiratory system.

28. That being the case, how do you think respiration occurs in the earthworm?

Resources

Belinky, Charles R. and Jan L. Wassink. "Molluscs, Segmented Worms and Minor Phyla." *Survey of the Animal Kingdom: The Invertebrates.* Part II of a four part filmstrip series with cassettes and guides. #FS 1058. Educational Images, Ltd.

Educational Dimensions. *Dissection: Earthworm.* #52-4345. 1 filmstrip and cassette, available from Carolina Biological.

National Geographic Society. *A Tidal Flat and its Ecosystem.* 1979 video available from the National Geographic Society, 17th & M Streets, Washington, DC 20036.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

Annelida
aortic arch
buccal cavity
calciferous gland
clitellum
coelom
crop
earthworm
gizzard
metamerism
nephridia
prostomium
seta
typhlosole

Review

31. Earthworms

Name ____________________

Date ____________________

Practical: identify the numbered pins in the earthworm specimen provided by your instructor.

External Features

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

Internal Features

6. ____________________
7. ____________________
8. ____________________
8. ____________________
10. ____________________

Matching

______ 11. ventral nerve cord

______ 12. sperm vesicles

______ 13. aortic arches

______ 14. crop

______ 15. dorsal blood vessel

______ 16. epidermis

______ 17. esophagus

______ 18. intestine

______ 19. nephridia

______ 20. buccal cavity

A. carries food

B. stores food

C. holds food until it is swallowed

D. removes wastes

E. absorbs digested foods

F. relays and coordinates reflexes

G. pushes bood into the dorsal artery

H. stores sperm from another worm until needed for fertilization

I. carries blood

J. forms the skin and serves as protection

Multiple choice

______ 21. Earthworms belong to the phylum
a. *Platyhelminthes*
b. *Porifera*
c. *Annelida*
d. *Nematoda*

______ 22. The cuticle is part of the
a. digestive system
b. endodermis
c. reproductive system
d. epidermis

______ 23. Another term for the segments of an earthworm is
a. metamere
b. nephridia
c. prostomium
d. clitellum

______ 24. The setae aid in
a. respiration
b. locomotion
c. digestion
d. excretion

______ 25. Reproduction in an earthworm may occur at any time of the year, but happens most often in the
a. winter
b. fall
c. spring
d. summer

______ 26. Blood circulation within the *Annelida* is by
a. simple diffusion
b. heat differential
c. blood vessels
d. open cavities

______ 27. Ferilization in an earthworm takes place in the
a. vas deferens
b. worm itself
c. ovary
d. cocoon

______ 28. The mouth of an earthworm is overhung by a
a. prostomium
b. clitellum
c. lumbricus
d. cuticle

______ 29. the earthworm possesses
a. circular muscles
b. longitudinal muscles
c. circular and longitudinal muscles
d. parapodial muscles

______ 30. The digestive tract of an earthworm is divided into a number of parts. They are, **in order:**
a. mouth, buccal cavity, pharynx, esophagus, crop, gizzard, intestine, anus.
b. mouth, pharynx, esophagus, buccal cavity, crop, intestine, gizzard, anus.
c. mouth, buccal cavity, intestine, crop, esophagus, pharynx, gizzard, anus.
d. mouth, crop, esophagus, buccal cavity, pharynx, gizzard, intestine, anus.

32. Laboratory

Clams

When you have completed this laboratory you should be able to:

1. Understand the structures and life cycles of molluscs.
2. Identify and label the organ systems of a clam.

Phylum *Mollusca*

The molluscs constitute one of the largest phylum of animals, both in numbers of different species, some 48,000, and in numbers of individuals. The phylum *Mollusca* includes chitons, clams, scallops, oysters, snails, slugs, octopuses, squid, and chambered nautiluses. The Latin word *mollus* means "soft," and these animals are characterized by having soft bodies, generally protected by a hard, calcium containing shell. The ventral part of their bodies usually forms a foot, a muscular structure used in locomotion.

Molluscs, like the *Annelida*, have a coelum, a closed circulatory system, and excretory organs with nephridia. The structures of their nervous system can be quite complex. Unlike simpler animals, the molluscs are able to secrete a protective covering, or shell, to cover their soft bodies. In some, this primitive type of exoskeleton, or outer skeleton, is reduced to the point that the animal's body grows around it, becoming functionally somewhat like an endoskeleton. This occurs in some advanced molluscs, such as the squid.

The *Mollusca* includes three large classes and two smaller classes. The class distinctions in *Mollusca* are based primarily upon shell structure.

Minor Classes

The *Amphineura* is a small class of marine animals whose most familiar member is the chiton. The chiton has a dorsal shell composed of eight segments, which enables it to roll into a ball if threatened. Chitons slowly creep on a broad foot and slime secretions over rocks, mostly in tidal zones. Sometimes chitons stay in one place so long that they wear a depression in a rock and can not climb out. Chitons have a radula, a thin flexible strip of toothed skin which can be pulled around the end of the tongue. When the tongue is pushed against an object, the radula scrapes off a piece of the object, which the tongue then collects for swallowing.

The class *Scaphopoda* is commonly known as the tooth shells. They have a conical shell open at both ends. They are marine animals which burrow in mud and sand, using their foot to dig. They too possess a radula. Their shells were used by American west coast Indians as money, and even today these shells are popular with collectors.

Gastropoda

The *Gastropoda*, or "stomach footed," often have a single dorsal shell which is usually spiral in shape. The class includes the snails, slugs, whelks, and abalones. They are both large in numbers and economically important to man. Some are carnivores and some herbivores. The gastropods are found in both salt and fresh water environments, as well as on land. Snails and slugs are the only molluscs found on land. In common with other molluscs, they move by means of a foot and eat with a radula.

Cephalopoda

The *Cephalopoda*, or "head footed," are the most advanced animals among the invertebrates. There are about 600 living species, all marine animals. In many respects they are as complex in structure and as intelligent as some vertebrates. They are all active predators. The chambered nautilus is the only living cephalopod to retain a shell, and it uses the shell as a form of "house," occupying only the outermost portion and using the remainder as a flotation device. The squid and the cuttlefish have a shell which is so greatly modified that it is now an internal stiffening device, functionally similar to an endoskeleton. The octopus, however, has no shell at all.

All cephalopods have a large head with a conspicuous eye, and a central mouth surrounded by arms, some ninety in the chambered nautilus, ten in the squid, and eight in an octopus. They range in size from small to gigantic. A squid caught in the Atlantic some one hundred years ago measured some six meters long, not including the tentacles.

Pelecypoda

The *Pelecypoda*, or "hatchet footed," often have a highly developed foot. A clam, using its "hatchet foot," can dig into sand or mud with remarkable speed. Pelecypods have a double-valved shell, and they are often called bivalves. The valves are connected with hinged ligaments. There are approximately 7,500 different pelecypod species, and the class includes such common animals as clams, oysters, scallops, and mussels.

Clams and Digestion

The clam is a typical pelecypod. Clams, like most molluscs, possess three distinct body zones: a head-foot, which contains sensory organs; a visceral mass, which contains organs for digestion, excretion, and reproduction; and a mantle, a specialized tissue which enfolds the visceral mass and secretes the shell. Clams have well developed abductor (closing) and adductor (opening) muscles, which control the opening and closing of the shell valves. The mantle cavity, a space between the mantle and the shell, houses the gills, and the visceral mass discharges wastes and gametes into this cavity. Cilia on the gills sweep this discharge into the environment.

Conversely, organic debris brought into the cavity by the same ciliary action becomes food for the animal. Incurrent and excurrent siphons control the amount of water and debris swept in and out of the mantle cavity. The debris sticks to mucous on the gills, and the mucous is routed, via the labial palps (clam lips), mouth, and esophagus, to the clam's stomach. This feeding behavior is why clams and similar species have been referred to as mucous feeders. The clam possesses digestive glands in its stomach, a typhlosole intestine, and a rectum. The anus is connected to the excurrent siphon for waste removal.

Blood Circulation

The clam has a heart composed of one ventricle, a muscular pump, and two auricles, which are thin-walled blood reception areas. The heart is enclosed in a pericardial sac. From the ventricle a major blood vessel, the anterior aorta, takes blood out to the foot and parts of the visceral mass. Another major vessel, the posterior aorta, takes blood to the mantle and to the posterior portion of the digestive tract. Blood flowing through the sinuses, or cavities, of the mantle gives off carbon dioxide and picks up oxygen, after which it returns directly to the auricles. Other sinuses in the animal perform a similar function. Some sinus blood is drained into kidneys where it is cleaned and laden with carbon dioxide for movement to the gills where gas exchange takes place.

Respiration and Excretion

Clams have paired gills for respiration. They also obtain oxygen by simple diffusion through both the mantle and the skin. Excretion is accomplished through a pair of U-shaped kidneys which lie directly beneath the pericardial cavity and are partially united with it. Excretory pores open to the environment by way of a chamber in the inner gills.

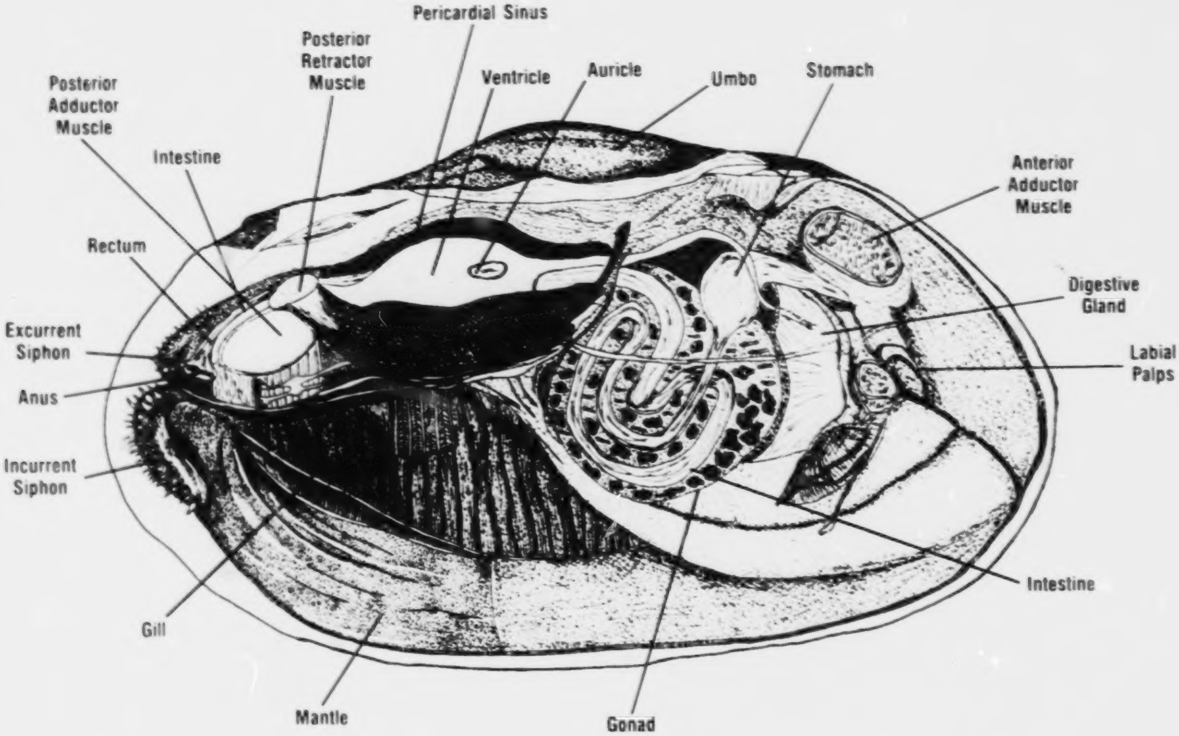
The Senses

Clams have three pairs of ganglia which can be considered to be a type of brain (for comparison, the earthworm has only two ganglia). They also possess sensory structures on the margins of the siphons, the mantle edge, and on their labial palps. A pair of statocysts, sensory organs for balance, are located in the foot. As is required for life inside a shell, the clam head has been much reduced.

Reproduction

Clam sexes are separate, but they are so similar in appearance that the non-expert cannot tell them apart. Their sex organs, or gonads, are located in the visceral mass. Fertilization is either external or internal. If it is external, both sperm and eggs are passed out excurrent siphons, and fertilization takes place in the water. Internal fertilization as we know it is impossible, because of the animals' shells; instead, the sperm of internal fertilizing species are released through a male's excurrent siphon, and they enter female clams through their incurrent siphons. Eggs are passed to spaces in the gills (the spaces being called marsupia), and fertilization and early development of embryos take place in the gill marsupia. Internal fertilization usually occurs in late summer. The baby clams remain in the gills during the winter months and are released in the spring.

Study figure one below for the placement of these organ systems in the body of the clam.


Pericardial Sinus
Posterior Retractor Muscle
Posterior Adductor Muscle
Ventricle
Auricle
Umbo
Stomach
Intestine
Anterior Adductor Muscle
Rectum
Digestive Gland
Excurrent Siphon
Labial Palps
Anus
Incurrent Siphon
Intestine
Gill
Mantle
Gonad

Clam Internal Structures

Figure 1

In this laboratory you will dissect a clam. You will study how clam structures relate to life functions, and you will identify and label the various organ systems.

Pre-lab

Supplies needed:

Equipment

Dissecting scope or hand lens probe scalpel dissecting pan scissors hammer

Materials

clam

Special Preparations

Clams may be either fresh or preserved. If they are preserved, make sure that the specimens have been pegged so that the student may open the shell easily. If they are fresh, the clam shells may be opened by light steaming. The visceral organs on preserved specimens are slightly hardened and therefore easier for the student to identify.

Time Required

The clams laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Place your specimen in a dissecting pan, and identify the following external features.

- Shell with two valves and hinge ligament: note the concentric lines on the shell. They are growth rings, with the newest part of the shell at the edges. The outer, horny shell layer is called the periostracum.
- Umbo: a swollen hump near the hinge. This is the oldest part of the shell.

1. Why are these animals sometimes called bivalves? ______________________________

____

2. What color is the periostracum? ______________________________

3. Can you see any areas where the periostracum has been eroded away? Where? ____________

____

B. Pry the ventral margins of the clam's valves apart with your scalpel blade and handle. Cut the two muscles which keep the valves closed. Leave the animal inside the left valve and remove the right valve. Crack the right valve in order to expose the three shell layers, namely, the periostracum, the prismatic or calcareous middle layer, and the nacreous or mother-of-pearl inner layer. Also remove the mantle from the animal to expose the mantle cavity and animal. Identify the following features.

- Mantle: a membrane which lines the inner surface of each valve.
- Mantle cavity: Space between the valves and the animal.
- Incurrent (larger and ventral) and excurrent (smaller and dorsal) siphons: at the posterior end of the animal.
- Anus.
- Anterior and posterior adductor muscles: you cut them in order to open the valves. Note also small retractor muscles which lie close to and slightly dorsal to the adductors. The retractor muscles draw the foot back into the shell.
- Teeth: these calcerous projections are near the hinge region of the valves. They fit together when the valves are closed. In some clam species the teeth are well developed, and in others they are very difficult to identify.
- Pallial line and muscle: where the mantle attaches to the valve. Sometimes pearls are found between the mantle and the valve, next to the inner layer of the shell called the nacreous layer, or mother-of-pearl layer.

4. Is the arrangement of the teeth the same on both valves? Why or why not? ______________

____

____

5. Why do you think pearls sometimes are formed between the mantle and the valves?

6. To what do the retractor muscles and adductor muscles attach? Can you determine their function from these attachments? What are their functions?

C. Now you will dissect the internal structures of the animal. Cut away the left mantle lobe to expose the pair of gills underneath. Lift the gills and examine the foot. Note where the foot merges with the visceral mass. Identify the following internal structures.

- Gills.
- Foot.
- Pericardial sac: a dark colored area just anterior to the posterior adductor muscle. The sac encloses the heart.
- Heart: expose it in the pericardial sac. Note the one ventricle (tougher tissue) and two thin-walled auricles which extend fan-like from the ventricle.
- Kidneys: these may be seen through the thin floor of the pericardial cavity. They are a dark, soft mass of tissue.
- Labial palps and mouth.
- Intestine and rectum: the heart lies on the dorsal side of the intestine.

7. In the space provided below, diagram the structure of the heart.

8. In the space provided below, diagram the kidneys.

D. Remove the entire body from the shell by loosening the right adductor muscles, and remove the right mantle lobe. Find the mid-dorsal line and cut ventrally with a very sharp scalpel, bissecting the entire animal, including the foot, into exact right and left halves. The cut will go through the center of the mouth. Examine both halves, and identify the following structures.

- Esophagus: leading from the mouth to the stomach.
- Stomach: a large structure taking up most of the visceral mass. The intestine leads from its ventral portion.
- Liver: greenish digestive glands surrounding the stomach.
- Gonads: a light brown, branched mass surrounding the intestine.

It is extremely difficult to identify the structures of the nervous system. Sometimes it is possible to see small white or yellowish tissue above the mouth or esophagus. These are ganglia.

9. In the space provided below, trace the digestive tract of a clam from the mouth to the anus. Label all strctures.

10. Explain how a clam obtains and digests food

11. What structures distinguish clams from other animals you have studied thus far in biology?

Resources

Marineland, Inc. *The Not-So Terrible Octopus.* #05397-910 video. The Center for Humanities, Inc.

Roper, Clyde F. E., and Kenneth J. Boss. "The Giant Squid." *Scientific American.* April 1981.

War, Peter, Lewis Greenwald, and Olive E. Greenwald. "The Buoyancy of the Chambered Nautilus." *Scientific American.* April 1980.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- endoskeleton
- exoskeleton
- foot
- labial palp
- mantle
- *Mollusca*
- *Pelecypoda*
- pericardial sac
- radula
- statocyst
- umbo

Review

32. Clams

Name______________________________

Date______________________________

Multiple choice

______ 1. Which of the following is not a member of the *Mollusca?*
a. squid
b. sea cucumber
c. clam
d. snail

______ 2. The swollen part of the shell of a clam is called the
a. periostracum
b. nacre
c. umbo
d. knob

______ 3. What is the main function of the mantle?
a. covers the visceral mass
b. protects the foot
c. provides food for the clam
d. secretes the shell

______ 4. What structures conduct respiration in the clam?
a. amoebocytes and gills
b. foot and mantle
c. dermal branchiae and mantle
d. mantle and gills

______ 5. Which of the following is not true of the clam circulatory system?
a. open
b. posterior and anterior aortas
c. three chambered heart
d. closed

______ 6. The clam exhibits
a. bilateral symmetry
b. radial symmetry
c. unilateral symmetry
d. none of these

______ 7. The heart of the clam is found in the
a. cardiovascular cavity
b. pericardial cavity
c. suprabranchial cavity
d. periestracal cavity

______ 8. The function of the adductor muscle is to
a. retract the foot
b. extend the foot
c. close the shell
d. extend the visceral mass

______ 9. The statocyst serves the clam as an organ of
a. sight
b. sound
c. balance
d. smell

______ 10. Internally fertilized clam embryos live in marsupia on the clam's
a. gonads
b. gills
c. excurrent siphon
d. anus

Order the following intestinal sequence correctly.

______ 11.

______ 12.

______ 13.

______ 14.

______ 15.

______ 16.

______ 17.

______ 18.

______ 19.

______ 20.

A. esophagus

B. intestine

C. rectum

D. incurrent siphon

E. mouth

F. stomach

G. anus

H. excurrent siphon

J. labial palps

K. mucous on gills

33. Laboratory

Starfish

When you have completed this laboratory you should be able to:

1. List typical echinoderm body characteristics.
2. Understand typical echinoderm developmental patterns.
3. Dissect and identify the major external and internal organ systems and structures of a starfish.

Phylum *Echinodermata*

The phylum *Echinodermata* is so named because many members of the phylum possess a spiny skin. It includes about 6,000 species divided into five classes of salt water animals, namely, the starfish (class *Asteroidea*), brittle stars (class *Ophiuroidea*), sea urchins and sand dollars (class *Echinoidea*), sea cucumbers (class *Holothuroidea*), and sea lilies (class *Crinoidea*). There also are several extinct classes.

The enchinoderms are the simplest animals to have an endoskeleton and also to have a deuterostome embryonic developmental pattern. The deuterostome type of embryonic development basically means that the anus of the animal appears before the mouth. All echinoderms, as well as all vertebrate animals (those with a backbone), such as man, exhibit the deuterostome type of embryonic development.

Coelom Development in the Embryo

As you will recall, sponges and coelenterates possess only two-cell layers, and a coelom, or body cavity, does not develop. Flatworms have three-cell layers but no coelom. The unsegmented roundworms have a body cavity, but, in terms of embryonic development, it is not considered to be a "true" cavity. It consequently is called a pseudocoelom, or false cavity. Earthworms and other annelids, as well as the molluscs and the *Arthropoda* (see laboratory thirty-four), have three-cell layers and a true coelom. However, during embryonic development, the mouth appears before the anus, and the embryonic development pattern in the annelids, molluscs, and *Arthropoda* is called protostomate. This occurs because the cleavage pattern during early cell division is spiral. The mouth develops at or near the blastopore, the area in an embryo where endodermal and epidermal tissues meet, and the coelom results from a splitting of the mesoderm.

In the deuterostomes, such as the echinoderms, and chordate animals (see laboratory thirty-five), such as the vertebrates, the cleavage pattern during early cell division is radial, with the anus developing at or near the blastopore and with the mouth forming secondarily elsewhere. The coelom subsequently is formed by outpocketings of the embryonic gut. Only two minor phyla, the arrow worms and the acorn worms, other than the echinoderms and chordates, exhibit this type of embryonic development.

Phylum Characteristics

All echinoderms, such as starfish, exhibit radial symmetry as adults, usually with a five part body plan. However, the larval forms are bilaterally symmetrical; during the change from larval to adult form a severe metamorphosis, or change in form, occurs. This involves a drastic alteration of body plan and form, with, for example, the left side of a starfish larval body becoming the bottom of the adult and the right side changing into the top side.

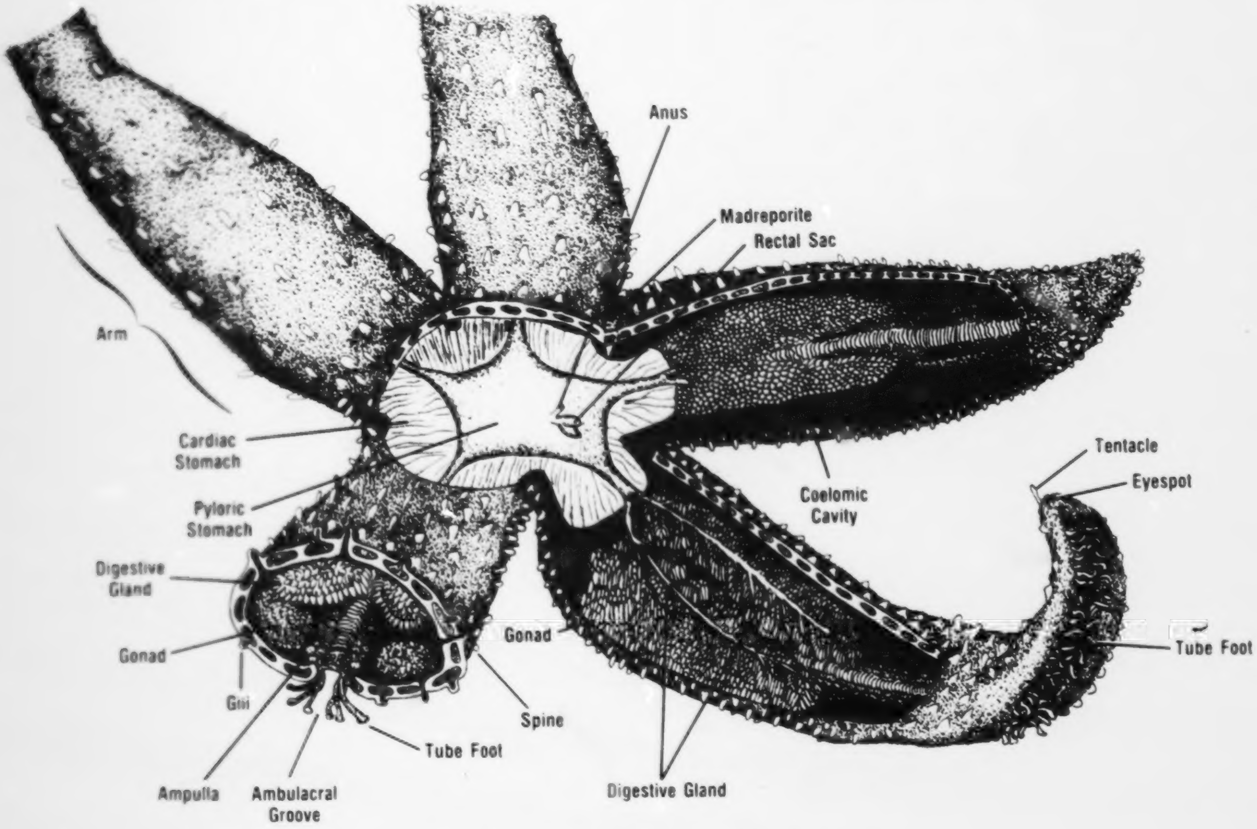
A highly distinctive characteristic of echinoderms is their water vascular system. It derives by modification of the coelom into a complex set of internal canals. At the top of the starfish is the water inlet, called a madreporite plate, and leading from the inlet and central ring canal are feeder canals which radiate out into each arm. These in turn connect to smaller canals which eventually attach to the tube feet. Through contractions and relaxations of muscles enveloping the ampullae, bulb-like structures at the terminus of the smallest canals and at the internal end of each tube foot, hydrostatic pressure is created which provides suction in the tube feet. These actions provide both locomotion and prying power with which a starfish opens shellfish in preparation for feeding. The water vascular system also brings aerated water into the animal for respiration.

An echinoderm's limy endoskeleton is covered by a delicate epidermis through which many spines, or calcareous plates, protrude. These common marine animals are all free-living. They are typically slow-moving or sessile tidal zone dwellers. They have no head, no brain, and no segmentation. Their digestive tracts are complete, although some species have lost the anus. The term "lost" is used because the anus forms early in the animal's development and then disappears in later life stages.

The same pattern of development and subsequent disappearance repeats with the circulatory and nervous systems, in that the active larvae have more complete systems than do the more sedentary adults. In the adults, respiration is accomplished by minute gills protruding from the tube feet, epidermal gills, and simple diffusion. Such reduction of physiological capabilities in adult echinoderms is why they are sometimes known as the degenerates of the animal kingdom, no pun intended.

Starfish

All starfish belong to the class *Asteroidea*. In this laboratory you will study the structure of a typical starfish, *Asterias*, as shown in figure one below. Refer to this drawing as necessary during the laboratory.



Starfish Internal and External Structures

Figure 1

Pre-lab

Supplies needed:

Equipment

- dissecting pan
- scissors
- forceps
- dissecting scope or hand lens
- probe

Materials

preserved starfish

Special Preparations

None.

Time Required

The starfish laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Place your specimen in a dissecting pan, and identify the following external features.

- Dorsal (top) and ventral (bottom) sides.
- Madreporite: a fine meshed sieve that opens into a part of the coelom on the dorsal side of the animal.
- Arms (five rays or body parts) and the central disc (where the arms come together).
- Spines and tubercles: on the dorsal side of the body. Tubercles are calcareous bumps; spines are jointed at the base and supplied with muscles so that they can be pointed in different directions. Each skeletal piece is secreted as a single crystal of calcium carbonate. The epidermis on the spines is usually worn off.
- Dermal gills and pedicellariae: on the dorsal side of the body. These cannot be seen without the aid of a good dissecting scope. Pedicellariae are microscopic pincers clustered around the bases of spines. They keep at bay those organisms which might otherwise attach to the starfish. The dermal gills may be difficult to see in your preserved specimen.
- Anus: in the center of the disc on the dorsal body surface. It is very difficult to see, even with a dissecting scope.
- Tube feet: on the ventral body surface. They number in the hundreds, terminate in suckers, and are used for both locomotion and preparing prey for feeding.
- Ambulacral grooves: on the ventral body surface. They radiate from the central disc along the lower surface of each arm. The tube feet project in longitudinal staggered double rows from the ambulacral grooves.
- Mouth and peristome: on the ventral body surface. The mouth is in the center of the lower surface surrounded by the peristome, a membranous area.
- Eyespots and tentacles: at the tips of the arms. Each eyespot is composed of about one hundred pigment cups, each lined with a layer of retinal cells. The starfish demonstrates only generalized reactions to light. A tentacle, a suckerless tube foot, usually overhangs each eyespot.

1. What is the color of your starfish? ____

2. What form of symmetry does your starfish exhibit? ______________________________

3. In the space provided below, draw a tube foot.

B. Turn your starfish dorsal side up in your dissecting pan. Remove the tip of one of the arms. Cut the dorsal skeleton up to the central disc, making a longitudinal cut on each side of the arm from which you have removed the tip. Remove the endoskeleton to expose the interior of the arm. The large gland filling the interior of the arm is a pyloric digestive gland. These glands, one in each arm, attach to the animal's stomach located in the central disc. Remove the entire pyloric digestive gland from the arm. Study the gland. It produces enzymes which reduce food to a broth so that it can be absorbed by the gastrodermis lining of the glands and stomach.

You may occasionally obtain a specimen for dissection which was collected and preserved during spawning season. If this happened to your specimen, there may be large gonads under the pyloric digestive gland which can be seen. The sexes are separate, and testes are gray in color, while ovaries are orange. The gonads are attached to reproductive pores, and fertilization is external. Normally, however, the gonads and reproductive pores are too small to see, even with a dissecting scope.

4. How many digestive glands does each starfish have? ________________________________

C. Carefully cut away the top surface of the cental disc. Cut around the madreporite plate. Identify the following organs and structures.

- Stomach: a large sac-like organ attached to the mouth. It almost completely fills the central disc. It consists of a large cardiac stomach and a smaller pyloric stomach. During feeding, the cardiac stomach everts through the mouth and spreads over the food. Enzymes secreted by the digestive glands pour over the food liquifying it. This broth is then swallowed and absorbed, and muscles pull the stomach back inside the starfish.
- Intestine: a small tube that connects the pyloric stomach to the anus.
- Rectal sac: a diverticulum off the intestine.
- Nerve ring: a ring of tissue encircling the mouth. Five radial nerves feed to the arms from this ring.

5. In the space provided below, draw the cardiac and pyloric stomachs as they are attached to the mouth and intestine. Label all structures.

6. Name the structures of the digestive system in a starfish in order from the mouth to the anus.

7. Describe the location, form, and function of the internal nervous system and external sensory organs of a starfish.

D. Remove the skeleton from the top of the other four arms. Remove all the digestive glands, stomach, and any visible gonads. Do not remove the madreporite plate or anything connected to it. The structures that remain in your starfish are all part of the animal's water vascular system. This system consists of a series of hollow tubes. Identify the following structures.

- Stone canal: leading from the madreporite plate to the ring canal.
- Ring canal: a circular canal joining five radial canals, one from each starfish arm. Radial canals are not visible in preserved specimens, but they are located inside the ambulacral grooves.
- Lateral canal: small canals which join each tube foot to each radial canal. Lateral canals are valved so that they can adjust the amount of water in the tube feet and ampullae.
- Ampulla: the inner structure of the tube foot. It is a bulb-like structure. The contractions in its muscular coat create the suction exerted by the tube foot. Ampulla are best studied with the dissecting scope.

8. In the space provided below, diagram the water vascular system of a starfish. Label all structures.

9. Describe how suction is generated in a tube foot.

10. Complete the review chart, figure two below, by filling all squares with key words. The "First to Have" line asks for the simplest animal which possesses a particular structure or function.

	Earthworm	**Clam**	**Starfish**
Phylum			
Class			
Symmetry			
Locomotion			
Life Type			
Coelom Type			
Habitat			
Digestion			
Excretion			
Respiration			
Nervous System			
Asexual Reproduction			
Sexual Reproduction			
Simplest Animal to Have			
Other Members			

Figure 2

Resources

Belinky, Charles R. and Jan L. Wassink. "Noninsect Arthropods and Echinoderms," *Survey of the Animal Kingdom: The Invertebrates*. Part IV of a part four filmstrip series with cassettes and guides, #FS 1058, Educational Images, Ltd.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

ambulacral groove
ampulla
Asteroidea
central disc
deuterostome
Echinodermata
madreporite
pedicillariae
peristome
protostome

Review
33. Starfish

Name____________________________

Date____________________________

Multiple choice

______ 1. Respiration in the starfish is carried on by the
a. gills c. pedicellariae
b. spines d. dermal branchia

______ 2. The sieve-like structure on the dorsal side of the starfish is the
a. madreporite c. ampulla
b. stone canal d. spine

______ 3. Which of the following is not true of the starfish?
a. radial symmetry c. water vascular system
b. well defined head d. body parts usually in fives

______ 4. The starfish is
a. monoecious c. dioecious
b. hermaphroditic d. none of these

______ 5. The function of the water vascular system is for
a. locomotion c. gripping
b. food capture d. all of the above

______ 6. Which of the following structure is **NOT** found on the dorsal side?
a. madreporite c. mouth
b. spines d. anus

______ 7. The bulb-like part of the tube foot in the starfish is the
a. sucker c. scolex
b. ampulla d. coelom

______ 8. The groove found on the lower side of the starfish arms is called the
a. ambulacral c. cardial
b. pyloric d. pericardial

______ 9. The starfish eats by
a. ingestion of small particles strained from the water
b. diffusion through the dermal branchia
c. suction using the muscular pharynx
d. everting the stomach over the prey.

______ 10. Which of the following structures is **not** found in the starfish?
a. radial nerve c. central disc
b. labial palps d. radial canals

______ 11. The class to which the starfish belongs is the
a. *Asteroidea*
b. *Echinodermata*
c. *Asterias*
d. *Aster*

______ 12. The starfish has a(n)
a. exoskeleton
b. endoskeleton
c. chitonous skeleton
d. no skeleton

______ 13. Echinoderms display what type of embryonic development?
a. stomate
b. protostome
c. deuterostome
d. complete metamorphosis

______ 14. Starfish have
a. teeth
b. auricles
c. heads
d. eyespots

______ 15. The circulatory system of a starfish is called a(n)
a. water vascular system
b. circumoral ring system
c. closed circulatory system
d. none of the above

34. Laboratory

Crayfish

When you have completed this laboratory you should be able to:

1. Understand the structures and life cycles of the *Arthropoda*.
2. Identify the structures of a crayfish and relate its specialized appendages to their various functions.
3. Identify and label the organ systems of a crayfish.

Phylum *Arthropoda*

The phylum *Arthropoda*, or "jointed foot" animals, contains most of the known animals in the world. The phylum has nearly one million species, and it is estimated that 10^{18} (a billion billion) individuals are alive at any one time. The phylum includes all crabs, shrimps, and barnacles (class *Crustacea*), insects (class *insecta*), spiders, scorpions and ticks (class *Arachnida*), centipedes (class *Chilopoda*), and millipedes (class *Diplopoda*). Arthropods live nearly everywhere in the world, from the tops of mountains to the depths of oceans, in the air, on land, in water, and in or on other organisms.

Phylum Characteristics

The arthropods, like members of *Annelida*, show an obvious pattern of bilateral symmetry and external body segmentation. In arthropods, however, there are usually three distinctive segments, the head, thorax, and abdomen. All arthropods have a hardened exoskeleton containing chitin (see exercise four), which is secreted by the epidermis and molted at intervals to allow for growth.

The appendages contain a few to many hinged joints, with one or more pairs of appendages per segment. The appendages can be highly differentiated, just as the animal itself can be narrowly specialized to live in a particular ecological niche. This extreme adaptability is one reason for the great success of arthropods. On the other hand, once an insect, for example, becomes highly specialized, the individuals of that species cannot adapt to changes in their environment.

All arthropods have a complete digestive tract from mouth to anus, with mouth parts variously adapted for chewing or sucking and with lateral jaws. The circulatory system is open but with a dorsal heart which distributes blood via arteries to organs and tissues. Blood returns to the heart through sinuses, or body spaces. Like molluscs, the coelom is greatly reduced. This becomes obvious during dissection.

All arthropods have complete muscular and respiratory systems. Often the muscles are complex structures, capable of rapid response. Arthropod respiratory systems are well developed, with respiration being accomplished by gills, trachea (air ducts), book lungs (layered air ducts), or by diffusion through the body surface.

Arthropods also are endowed with a brain (in paired dorsal ganglia over the mouth area) which connects to a pair of ventral nerve cords, and with a ganglion (nerve bundle) in each segment, as well as with ganglia concentrated in sensory organs. Their sensory organs can be highly developed and include both tactile and chemoreceptive antennae and sensory hairs, simple and compound eyes, auditory organs (class *Insecta*), and statocysts (class *Crustacea*) which function as balancing organs like those found in the molluscs.

Finally, arthropods usually have separate sexes (they are dioecious), with the male and female arthropods often looking unlike each other. Fertilization is usually internal, with shelled, heavily yolked eggs resulting. Arthropods usually have one or more larval stages and a gradual or abrupt metamorphosis to adult form.

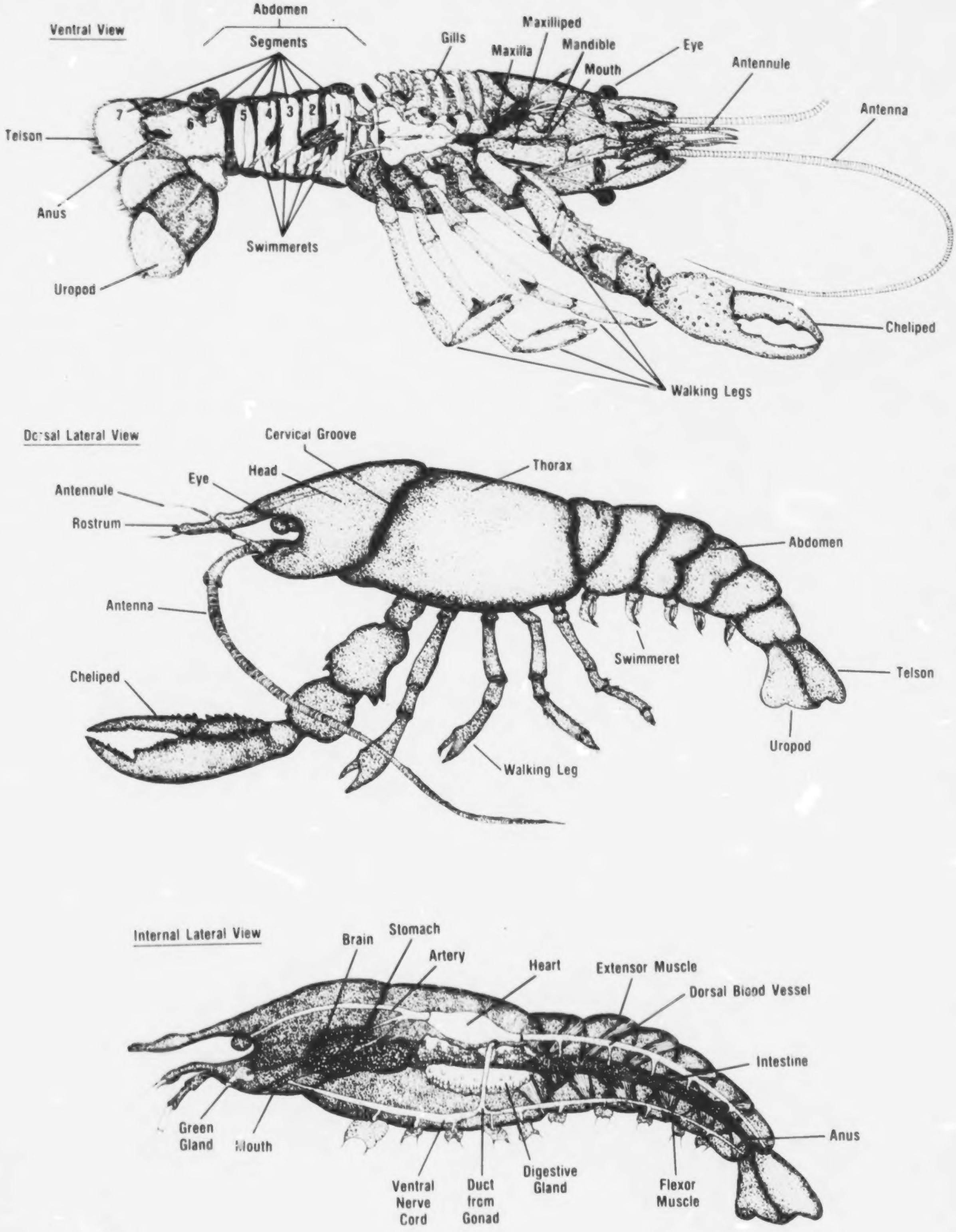

Ventral View
Abdomen
Segments
Maxilliped
Gills
Maxilla
Mandible
Eye
Mouth
Antennule
Antenna
Telson
7
6
5
4
3
2
1
Anus
Swimmerets
Uropod
Cheliped
Walking Legs
Dorsal Lateral View
Cervical Groove
Eye
Head
Thorax
Antennule
Rostrum
Abdomen
Antenna
Swimmeret
Telson
Cheliped
Uropod
Walking Leg
Internal Lateral View
Brain
Stomach
Artery
Heart
Extensor Muscle
Dorsal Blood Vessel
Intestine
Anus
Green Gland
Mouth
Ventral Nerve Cord
Duct from Gonad
Digestive Gland
Flexor Muscle

Figure 1

Some arthropods have the ability to undergo parthenogenesis, or virgin birth. Parthenogenesis is the ability of unfertilized gametes to divide, grow, and develop into mature individuals. It is no joke when people say that a single cockroach can infest an entire house.

Class *Crustacea*

In this laboratory you will study a crayfish, genus *Cambarus* of the class *Crustacea*, as representative of the entire crustacean class. You will identify its many external structures and relate these specialized appendages to their functions. Study the drawing in figure one and refer to it as you proceed with the laboratory.

Pre-lab

Supplies needed:

Equipment

dissecting scope or hand lens
scissors
probe
dissecting pan
forceps

Materials

preserved crayfish
glue
construction paper

Special Preparations

Provide one sheet of notebook sized construction paper to every laboratory group. Any stiff, preferably colored, paper can be used in place of construction paper. Laboratory results can make a nice classroom display.

Time Required

The crayfish laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Place the preserved crayfish on a dissecting tray, dorsal side up. With fingers or forceps, raise the back or posterior edge of the carapace. Cut forward along the dorsal surface of the carapace to the rostrum, without disturbing any of the organs under the carapace. Identify the following external features of the head region.

- Carapace: the part of the exoskeleton which covers the dorsal and lateral surfaces of the head and thorax.
- Cervical groove: a groove on the carapace which marks the division between the head and the thorax.
- Rostrum: the pointed anterior end of the carapace.
- Compound eyes: these are on short stalks near the rostrum.
- Antennules: near the rostrum and compound eyes. Sensory appendages.
- Antennae: also near the rostrum and compound eyes. They are two very long sensory antennae which trail backwards over a crayfish body. The animal's statocysts are located at the base of these antennae.
- Mouth: located on the ventral surface of the head.
- Mandibles: located just dorsal to the mouth. They are heavy, hard, jaw-like structures.
- First and second maxillae: appendages located just posterior and ventral to the mandibles. The second maxillae are modified to form a bailer, or thin indented plate, which circulates water through the gill chamber of the animal. Both maxillae pass food forward to the mouth.

1. Remove each external head structure from the right side of the crayfish as you identify it, and glue each structure onto a sheet of construction or similar paper, in an order like that of your crayfish. Label each crayfish part as it is glued onto the paper. Label your crayfish identification sheet with today's date, your name, as well as the names of other members of the laboratory group.

B. Identify the following external features of the thorax region. There are eight pairs of appendages on the thorax, one pair for each thoracic segment.

- First, second, and third maxillipeds: the first three pairs of appendages on the thorax posterior to the head. They tear and pass food to the mouth.
- Cheliped: the next appendage pair on the thorax posterior to the head. These are large, pinching legs used in fighting and foraging.
- Walking legs: the last four pairs of thoracic appendages. If one of these legs is torn off or shed because of injury, the crayfish can regenerate it. The ability to shed a damaged appendage is called autotomy, and the muscles which make this possible without undue loss of body fluids are located at the base of the walking legs.
- Oviduct openings: **in females only.** The openings are located at the bases of the third pair of walking legs.
- Seminal receptacle: **in females only.** It is located on the ventral mid-line, between the bases of the fourth and fifth walking legs.
- Sperm duct openings: **in males only.** The openings are located at the bases of the fifth pair of walking legs.

2. Remove each external thoracic structure from the right side of the crayfish as you identify it, and glue each structure onto the identification sheet, in an order like that of your crayfish. Label each crayfish part as it is glued onto the paper.

C. Identify the following internal features of the thorax.

- Gills: feathery structures attached to the bases of the walking legs. Remove them in order to see other internal organs.
- Stomach: the large black organ attached to the mouth by an esophagus, and posteriorly, to the intestine. Remove the stomach and cut it longitudinally. The large part of the stomach closest to the mouth is called the cardiac stomach, and the smaller section posterior to the cardiac stomach is called the pyloric stomach.
- Gastric mill: a structure composed of three calcified teeth. It is located where the cardiac and pyloric stomachs meet. The gastric mill is best observed under a dissecting scope, or hand lens.
- Green glands: the kidneys, or excretory organs, of the crayfish. They are located at the base of the antennae, anterior to the stomach. These glands pass wastes to the outside through an excretory pore located at the base segment of each antenna.
- Brain: located dorsally to the green glands. Use a dissecting scope to search for this whitish tissue. Attached to the brain are the ventral nerve cords.
- Digestive gland: located on the ventral side of the stomach. It is a long, whitish organ.
- Gonads: located posteriorly and dorsally to the stomach, directly under the dorsal heart. It is a whitish, granular organ in appearance, slightly or much smaller than the digestive gland, depending upon the sex and age of your crayfish. It is called the ovary in a female and testis in a male.
- Heart: located dorsally to all other organs in the crayfish, just anterior to where the carapace joins the abdomen.

3. Remove each internal organ from the head and thorax as you identify it, and glue them onto the identification sheet, in an order like that of your crayfish. Label each crayfish part as it is glued onto the paper.

D. Identify the following external features of the abdominal region.

- Swimmerets: abdominal appendages. In the male, the first two anterior pairs are modified for transferring sperm to the female. In the female, these first two pairs are reduced in size. The next three swimmeret pairs aid in the movement of water, and, in the female, for the attachment of eggs.
- Uropods: the sixth pair of swimmerets. These are greatly modified swimmerets.
- Telson: a terminal body appendage which, together with the uropods, forms a powerful tail-fan used to swim backwards.
- Anus: on the ventral side of the telson.

4. Remove each external abdominal structure from your crayfish as you identify it, and glue them onto the identification sheet, in an order like that of your crayfish. Label each crayfish part as it is glued onto the paper.

   D. Identify the following external features of the abdominal region.

   - Muscles: the abdomen consists of a large extensor muscle which covers the dorsal area and a large flexor muscle which covers the ventral area. Between the two muscles lie the intestines. There also is a ventral nerve cord and a dorsal blood vessel.

5. Remove each internal abdominal structure from your crayfish as you identify it, and glue each of them onto the identification sheet, in an order like that of your crayfish. Label each crayfish part as it is glued onto the paper.

Leave your crayfish identification chart in a secure, dry area for several hours. This will allow the glue and crayfish parts time to dry.

Resources

Bailey Film Associates. *Insect Metamorphosis.* #167 film, 11559 Santa Monica Boulevard, Los Angeles, California 90025.

Fitzgerald, Terance D. "Caterpillar on a Silken Thread," *Natural History*, February 1983.

Ken Middleham Productions. *Life Cycle of the Monarch.* Film, P.O. Box 1065, Riverside, California 92502.

Montgomery, Steven L. "The Case of the Killer Caterpillars," *National Geographic*, August 1983.

The Smithsonian Institution. *Arthropods: an Introduction to Insects and Their Relatives.* #48-1627, slide set and cassette, poster, worksheets and puzzles, available from Carolina Biological.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

Arthropoda
carapace
cervical groove
cheliped
Crustacea
gastric mill
green gland
mandible
maxilla
parthenogenesis
rostrum
swimmeret
telson
uropod

Review

34. Crayfish

Name ______________________

Date ______________________

Multiple choice

______ 1. The gastric mill of the crayfish is located
  a. in the lower esophagus
  b. posterior end of the midgut
  c. posterior part of the cardiac stomach
  d. anterior end of the rectum

______ 2. Metabolic wastes of the crayfish are removed by the
  a. green glands
  b. digestive glands
  c. gastric mill
  d. maxillae

______ 3. If the crayfish were to have trouble with its statocysts, it would have difficulty in
  a. breathing
  b. balancing
  c. reproducing
  d. eating

______ 4. When crustaceans shed their skin, it is called
  a. molting
  b. malting
  c. mating
  d. undressing

______ 5. The crayfish is
  a. monoecious
  b. dioecious
  c. hermaphroditic
  d. both a and c

______ 6. In a crayfish gills are located near the
  a. antennae
  b. walking legs
  c. antennules
  d. swimmerets

______ 7. The arthropods are similar to the annelids in all of the following ways, except
  a. dorsal heart
  b. open circulatory system
  c. ventral nerve cord
  d. segmentation

______ 8. Butterflies are in the class
  a. *Crustacea*
  b. *Chilopoda*
  c. *Insecta*
  d. *Arachnida*

______ 9. The anus of the crayfish is found
  a. at the base of the antenna
  b. ventral to the telson
  c. at the base of the fifth pair of walking legs
  d. at the base of the third pair of walking legs

______ 10. The phylum of animals with the most members is the
  a. *Crustacea*
  b. *Insecta*
  c. *Annelida*
  d. *Arthropoda*

Identify the following crayfish structures, using the figure two diagram below.

______ 11. antenna

______ 12. antennule

______ 13. carapace

______ 14. cheliped

______ 15. rostrum

______ 16. telson

______ 17. uropod

______ 18. walking leg

______ 19. cervical groove

______ 20. compound eye

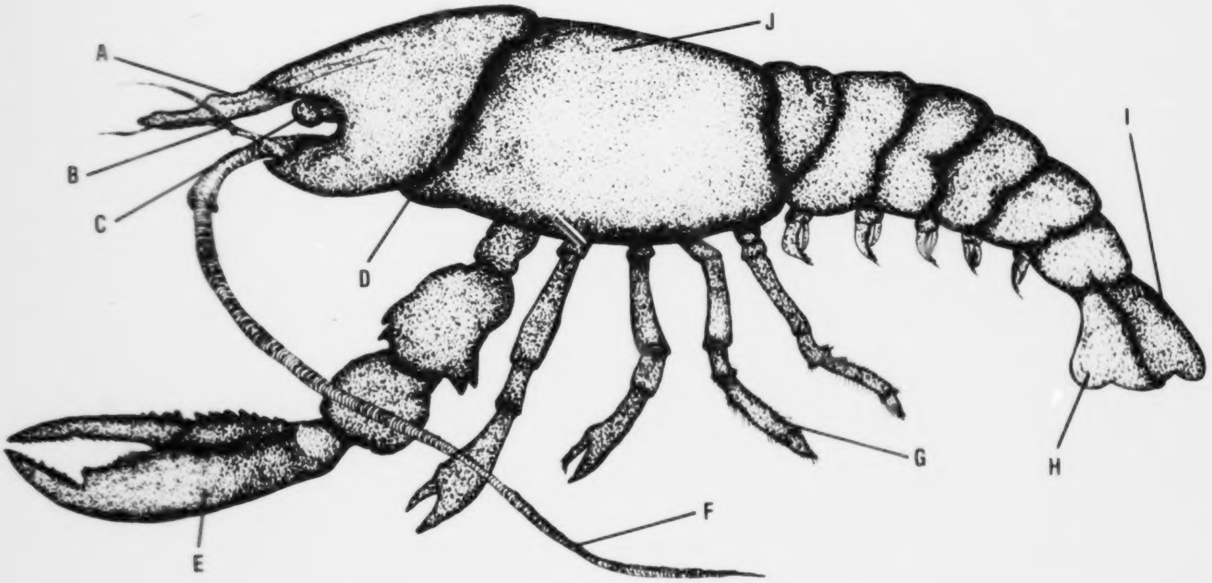
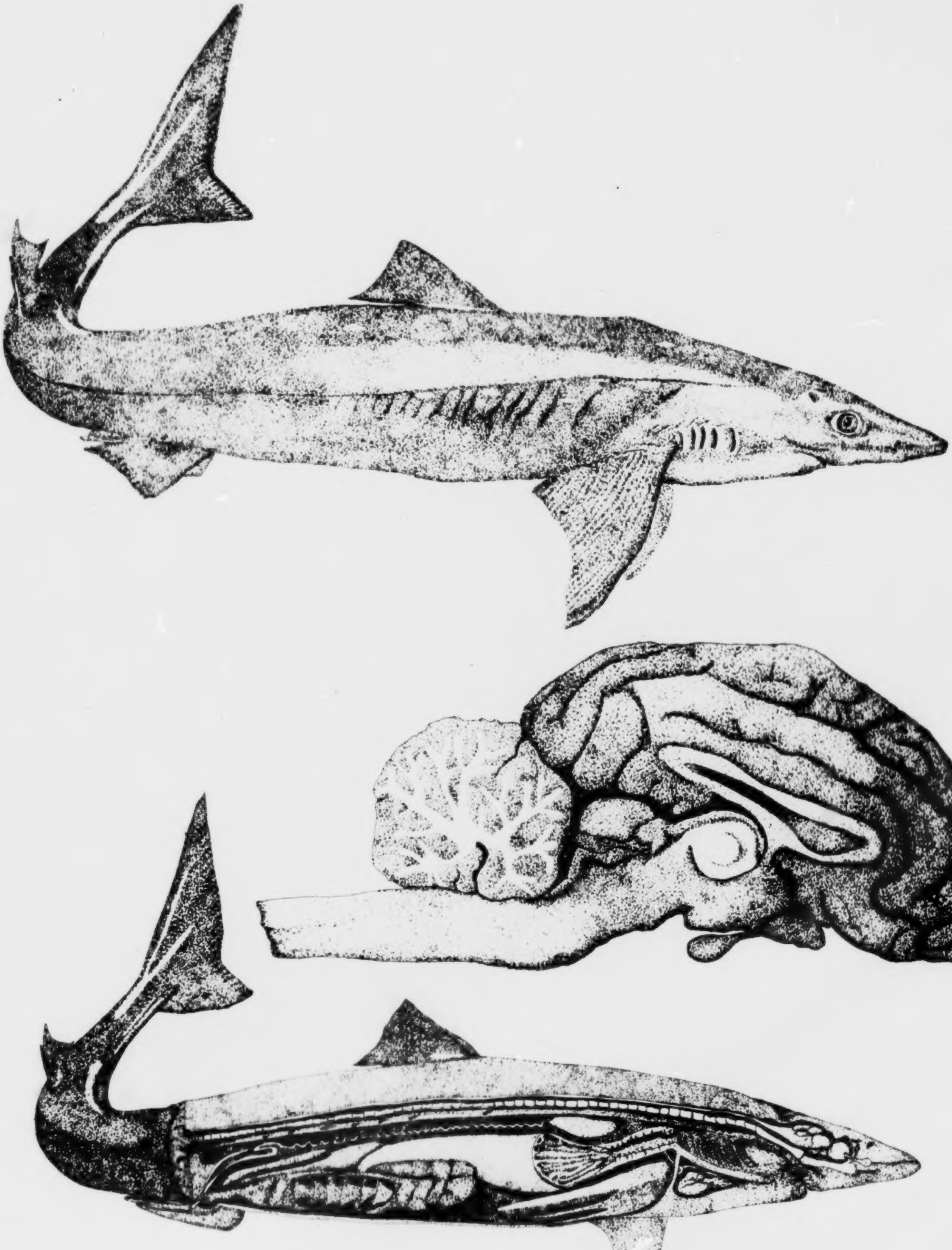


Figure 2

Vertebrates



35. Laboratory

Sharks

When you have completed this laboratory you should be able to:

1. Understand the structures and life cycle of the *Chondrichthyes.*
2. Identify the structures of a dogfish shark and relate its specialized appendages to their various functions.
3. Identify and label the organ systems of a shark.

Phylum *Chordata*

The phylum *Chordata* includes both vertebrates and invertebrates. All chordates possess a dorsal backbone, or other supportive rod, and also a dorsal nerve cord. The best known members of this phylum are vertebrates such as sharks, fish, birds, reptiles, and mammals. Man, of course, is a chordate.

Invertebrate Subphyla

The less well known chordates are invertebrates. They represent an important transition between invertebrates such as the crayfish and vertebrates such as the shark, which will be studied in this laboratory. The invertebrate chordates belong to two subphyla consisting entirely of soft-bodied, marine animals known as the lower chordates. Included in these subphyla, numbering only about one thousand species, are sea squirts and lancelets.

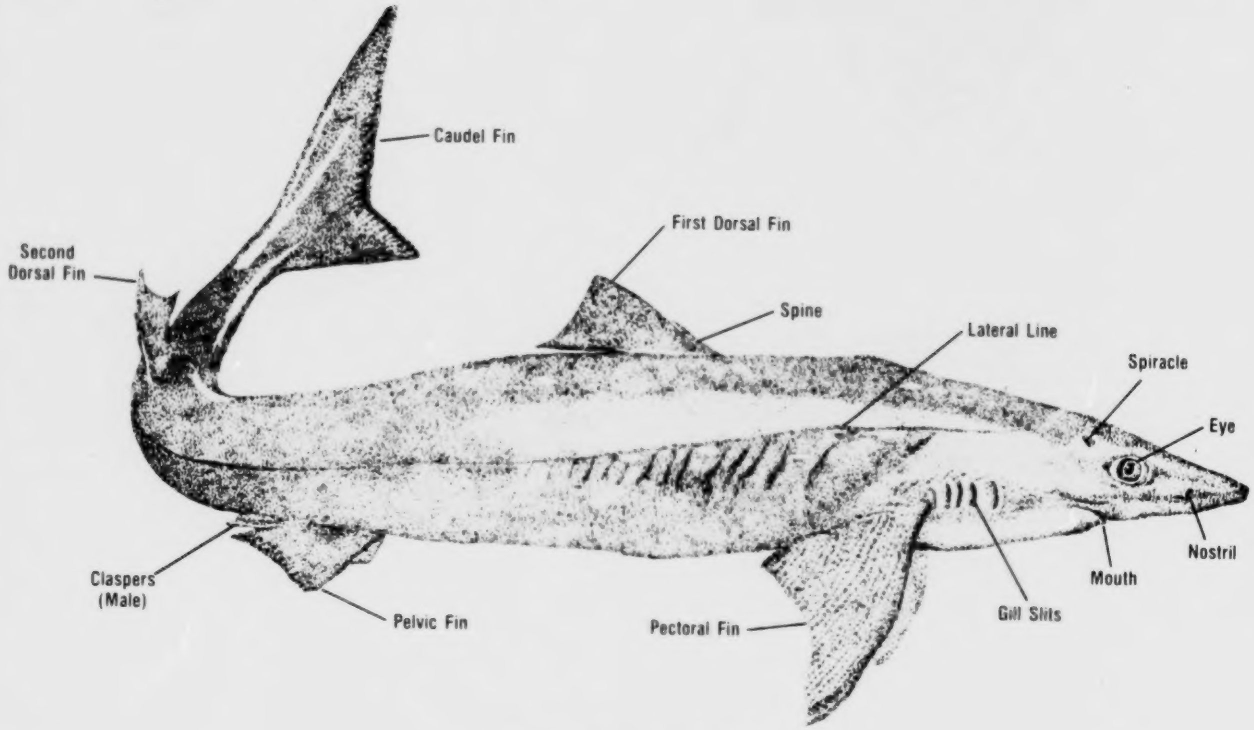
Although sea squirts and lancelets appear very different from each other, they do share three structural features common to all *Chordata.* Sea squirts and lancelets have a notochord, or dorsal longitudinal rod, as embryos, and sometimes even as adults. This rod is firm yet flexible, allowing the animal to move from side to side, or undulate, but not to contract and expand its body like a worm. Secondly, they have a longitudinal nerve cord dorsal to the notochord. This is very different from other invertebrates, which have ventral nerve cords, if any. Finally, they have pharyngeal (throat) pouches that extend laterally from the exterior part of the digestive tract toward the sides of the body, often breaking through the body wall as gill slits. All chordates domonstrate these three characteristics sometime during their life cycle.

Subphylum *Vertebrata*

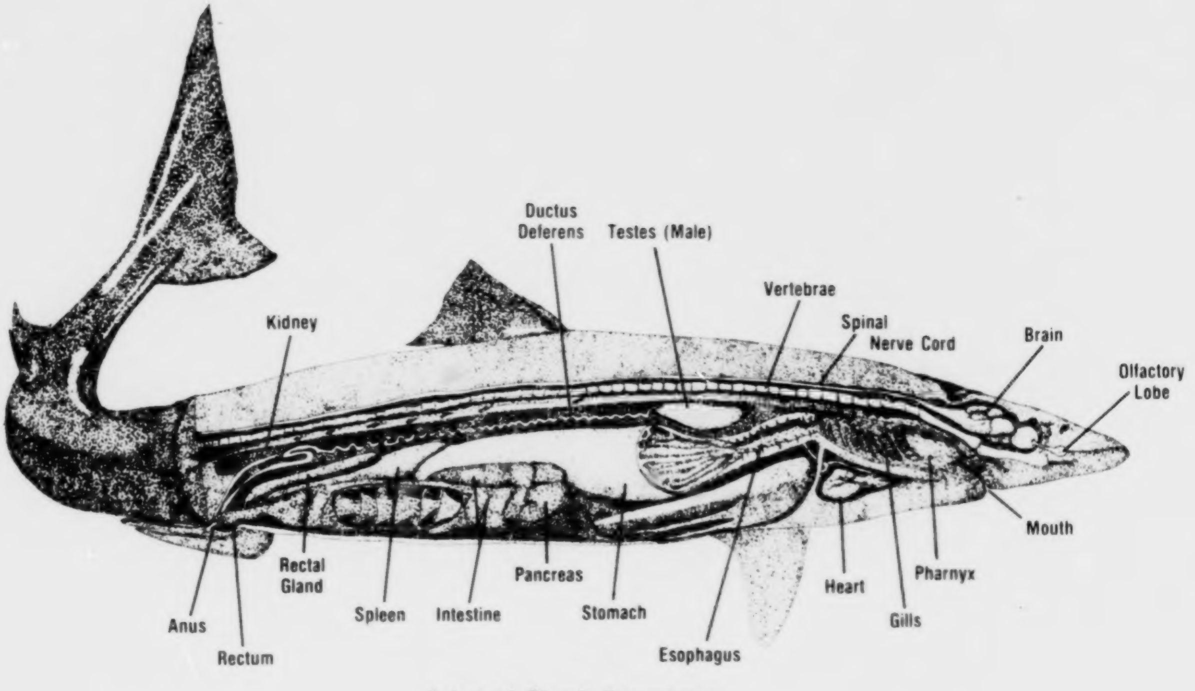
The subphylum *Vertebrata,* or those animals with a backbone, are by far the largest group of chordates, numbering about 42,000 species. Vertebrates are active animals with large accumulations of nerves and sense organs in the head. Their brains have three areas, a forebrain, a midbrain, and a hindbrain. A skull surrounds and protects the head. They usually have a tail. Also, they all have a bony endoskeleton with a vertebral column, or backbone, as the structural axis. The backbone is a flexible, usually bony, support that develops around the notochord and encircles the nerve cord along the length of the spine. In most higher vertebrates the backbone completely supplants the notochord. As embryos, the bones are almost totally cartilaginous, with bone gradually replacing the cartilage during the course of maturation.

The vertebrates also have similarities in their soft tissues. For instance, all vertebrates have red blood cells, kidneys, a solid liver, a pancreas, endocrine (hormone) organs, sense organs, and a balancing system located in the inner ears.

The subphylum *Vertebrata* includes the lampreys and hagfish (class *Agnatha*), the sharks, skates, and rays (class *Chondrichthyes*), bony fishes (class *Osteichthyes*), frogs, newts, and salamanders (class *Amphibia*), snakes, lizards, crocodiles, and turtles (class *Reptilia*), birds (class *Aves*), and man and other mammals (class *Mammalia*).


Caudel Fin
Second Dorsal Fin
First Dorsal Fin
Spine
Lateral Line
Spiracle
Eye
Nostril
Mouth
Gill Slits
Pectoral Fin
Pelvic Fin
Claspers (Male)

External Shark Structures


Ductus Deferens
Testes (Male)
Vertebrae
Spinal Nerve Cord
Brain
Olfactory Lobe
Kidney
Mouth
Rectal Gland
Pancreas
Pharnyx
Heart
Anus
Spleen
Intestine
Stomach
Gills
Rectum
Esophagus

Internal Shark Structures

Figure 1

Class *Chondrichthyes*

In this laboratory you will study the structures of a dogfish shark, *Squalus acanthias*, as characteristic of the *Chondrichthyes*, or cartilaginous fishes. Dogfish sharks are small, being only one-half to one meter in length, in comparison to some sharks, such as the whale shark, which can achieve a length of more than fifteen meters (fifty feet).

The sharks and their relatives are believed to be the first fishes to populate the ancient oceans more than 300 million years ago. The vertebrate ancestors of sharks were primarily freshwater animals known as placoderms. Sharks have retained some features of these ancient animals, such as sandpaper-like skin (the skin is covered with tiny tooth-like scales called placoid scales after their ancestors). They also have primitive tail structures. However, the sharks also differ from the placoderms, in that placoderms had bony skeletons. *Chondrichthyes*, on the other hand, have cartilaginous skeletons. It is believed that the *Chondrichthyes* demonstrate neoteny in this skeletal trait, in that the adult has retained an embryonic trait (see exercise twenty-two).

The Dogfish Shark

Study the two diagrams of the dogfish shark presented in figure one. You will identify many of the shark's external and internal structure during this laboratory and relate these structures to their functions. Refer to the figure one drawings when necessary as you proceed with the laboratory.

Pre-lab

Supplies needed:

Equipment

dissecting pan
scissors
forceps
probe
dissecting scope or magnifying glass

Materials

preserved dogfish shark
disposable gloves

Special Preparations

1) Sharks may be purchased from any biological supply house. Pregnant sharks are particularly interesting to dissect.

2) Disposable gloves are optional. However, the combination of preserving fluid and shark oil is truly memorable, and also long lasting. Make sure that the classroom is well ventilated, and warn the janitorial staff in advance that any spills are to be thoroughly mopped with soap and hot water. Disposable gloves should permit students to eat lunch without smelling shark with every bite.

3) The instructor should provide a cleaning area with plenty of soap and water. Students also probably will appreciate hand cream after working with sharks.

4) When working with preserved specimens, **especially** smelly sharks, students should not wear contact lenses. The fumes from the sharks can irritate contact lens covered eyes.

Time Required

The sharks laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Place the preserved shark on a dissecting tray, dorsal side up. Allow the shark's tail to hang over the end of the tray. Identify the following external structures.

- Dorsal and ventral sides.
- Placoid scales: feel and study the skin.
- Fins: identify the fins as shown in the figure one drawing. If your shark is a male, the posterior pelvic fins will be modified into claspers used to transfer sperm during copulation. Notice that the tail, or caudal fin has two lobes, with the dorsal lobe being larger than the ventral.
- Anus: a lump of flesh called the urogenital papilla usually protrudes from the anus.
- Spine: at the base of a dorsal fin.
- Gill slits.
- Lateral line: a light-colored stripe marks the position of this organ. The lateral line is sensitive to pressure changes in the water. In the head region, the lateral line is modified to sense electrical fields, which allows the shark to find hidden prey. This sensitivity to electrical fields is why sharks can be discouraged from visiting swimming areas by setting up an artificial electrical field in the water.
- Eye: the eye has a lens and retina with rods and cones, which suggests an ability to distinguish colors, but it is believed that shark vision is not very keen and that sharks rely heavily on other sensors.
- Spiracle: behind the eye. Water enters the pharynx of a shark through the spiracles.
- Nostrils: anterior to the mouth. The nostrils end in olfactory sacs containing chemoreceptors sensitive to chemicals in the water.
- Teeth: pry the mouth open to observe them. Be careful not to cut yourself on the sharp teeth.

1. Is your shark a male or female? How can you tell? ________________________________

____

____

2. How many gill slits do sharks have on each side of their bodies? ____________________

3. Remove a small section of skin from your shark and observe it under magnification. In the space provided below, draw a side view of a placoid scale.

4. How many rows of teeth does your shark have, and how do the rows differ from each other? __________

____

____

5. The shark constantly grows new teeth which eventually replace older, worn teeth. What might be the advantages of this characteristic?

____

____

____

____

6. Compare the similarities and differences between your shark's placoid scales and its teeth. ______

______

______

______

______

7. Are shark's teeth like your teeth? How or how not? ______

______

______

______

______

B. Open the shark's abdomen by cutting in a straight line through the skin and muscle from the anus to the head. Use scissors to cut through the cartilage between the two pectoral fins. Pin back the flaps of the body wall so that you have a clear view of the shark's internal organs. Use your probe to locate and identify the following internal organs.

- Esophagus: leads from the mouth to the stomach. Cut it open to see the papillae, or small protuberances of the dermis, inside the esophagus.
- Stomach: a J-shaped organ. Cut open the stomach to see if the last meal was digested.
- Small intestine: open it to see how it is constructed internally. This type of intestine is called a spiral valve intestine.
- Rectum: at the end of the intestine and attached to the anus.
- Rectal gland: attached to the rectum. The rectal gland secretes salt (sodium chloride) to osmotically regulate water in the shark's body.
- Pancreas: two lobes, one on either side of the upper part of the small intestine.
- Liver: three large lobes. Squeeze one of the lobes. It will be filled with oil critical to maintaining buoyancy. Open ocean sharks must either swim unceasingly, or sink, because they lack the gas bladder which provides buoyancy in bony fishes.
- Gall bladder: a greenish organ located underneath the liver.
- Spleen: a long, triangular-shaped organ lying alongside the stomach and small intestine.
- Kidneys: long bands of tissue which extend almost the entire length of the body cavity near the backbone. They drain through ducts into the rectum.
- Testes or ovaries: located near the anterior ends of the kidneys close to the esophagus. Attached to testes are long, thin tubes called ductus deferens used to transfer sperm from the testes to the anal area. Attached to the ovaries are long tubes called oviducts which also attach to the anal area of a shark. Oviducts may be long and thin, or filled with eggs. If your animal is a female with eggs, remove one of the eggs and open it to identify the yolk and embryo. Sharks fertilize their eggs internally, and dogfish shark females hold the fertilized eggs inside their bodies until the embryos hatch, at which point they are expelled live. This condition is called ovoviviparous development.
- Gills: located underneath the external gill slits. Sharks, in addition to maintaining buoyancy, must continuously swim to force water through the gill slits for respiration. Muscular actions in the floor of the mouth and in the gills themselves move water in and out of the gills.
- Heart: dorsal to the gills.
- Brain: it is difficult to dissect without mashing it into an unrecognizable mess. It is anterior to the mouth in the head region.

8. What did you find in your animal's stomach? ______

9. What might the advantage be in having a spiral valve intestine?

10. Why do you think that the shark is sometimes called nature's "eating machine"?

Resources

Apple. *Sharks: Their Nature and Evolution.* #C 3006, computer disc tutorial with quiz, available from Educational Images, Ltd.

Ellis, Richard. *Sharks of the World.* Filmstrip with text, available from Educational Images, Ltd.

Life Nature Library. *The Fishes.* Time-Life Books: Chicago, 1970.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- backbone
- *Chondrichthyes*
- *Chordata*
- gill slit
- lateral line
- notochord
- ovoviviparous
- placoid scale
- rectal gland
- *Squalus acanthus*
- *Vertebrata*

Review
35. Sharks

Name ______________________________

Date ______________________________

Multiple choice

______ 1. A cartilaginous skeleton is usually found in the
a. shark
b. snail
c. crayfish
d. squid

______ 2. The vertebrates have been successful because of
a. a protective body covering
b. a high reproductive rate
c. their development anaerobically
d. a relatively highly developed brain

______ 3. One characteristic of all vertebrates is
a. a dorsal heart
b. a bony skeleton
c. intelligent behavior
d. a dorsal nerve chord

______ 4. Which term applies to reproduction in a dogfish shark?
a. viviparous
b. oviparous
c. ovoviviparous
d. aviparous

______ 5. Which of the following structures is sensitive to underwater pressure variations, as well as electrical fields?
a. pineal body
b. cerebellum
c. notochord
d. lateral line

______ 6. Spiral valves in a shark are found in the
a. kidneys
b. intestines
c. pancreas
d. oviducts

______ 7. The scales of the shark are
a. placoid
b. ctenoid
c. dermoid
d. sharks do not have scales

______ 8. The tail fin of a shark is called
a. pectoral
b. pelvic
c. dorsal
d. caudal

______ 9. What organ serves to osmotically regulate the water content of a shark's body?
a. liver
b. pancreas
c. rectal gland
d. gas bladder

______ 10. Sharks belong to the class
a. *Agnatha*
b. *Aves*
c. *Osteichthyes*
d. *Chondrichthyes*

______ 11. Which organ helps a shark maintain its buoyancy in water?

a. liver
b. pancreas
c. rectal gland
d. gas bladder

______ 12. Which organ contains chemoreceptors that allow sharks to sense chemicals in the water?

a. lateral line
b. spiracle
c. rectal gland
d. olfactory sac

______ 13. Where are claspers found in a shark?

a. near the anus
b. near the dorsal fin
c. near the head
d. near the back teeth

______ 14. Water usually enters a shark's pharynx through the

a. mouth
b. gill slits
c. spiracles
d. claspers

______ 15. Sharks do not have

a. gills
b. pelvic fins
c. intestines
d. eyelids

36. Laboratory

Perch

When you have completed this laboratory you should be able to:

1. Understand the structures and life cycle of the *Osteichthyes*.
2. Identify the structures of a yellow perch and relate its specialized appendages to their various functions.
3. Identify and label the organ systems of a perch.

Class *Osteichthyes*

Members of the class *Osteichthyes*, the bony fishes, are believed to be descendants of the placoderms, as are the sharks. While early sharks established themselves in the oceans, bony fishes became dominant in fresh waters. Later bony fishes entered the oceans, as had the sharks before them, and eventually they became an even more successful group of salt water organisms.

Bony fishes differ from sharks, as their name suggests, in having a bony internal skeleton. This bone development is known as cartilage replacement bone, because it begins embryonically as cartilage and is ossified by calcium deposition as the organism matures. The bone in the scales and plates is called dermal bone, because it develops in the dermis of the skin and is not preceded by cartilage. Therefore, there are two types of bone in bony fishes, an internal skeleton and an external covering. We see a similar pattern in man, who possesses both an internal skeleton as well as external cartilaginous growths, the fingernails and toenails which arise from the dermis.

Gas Bladders

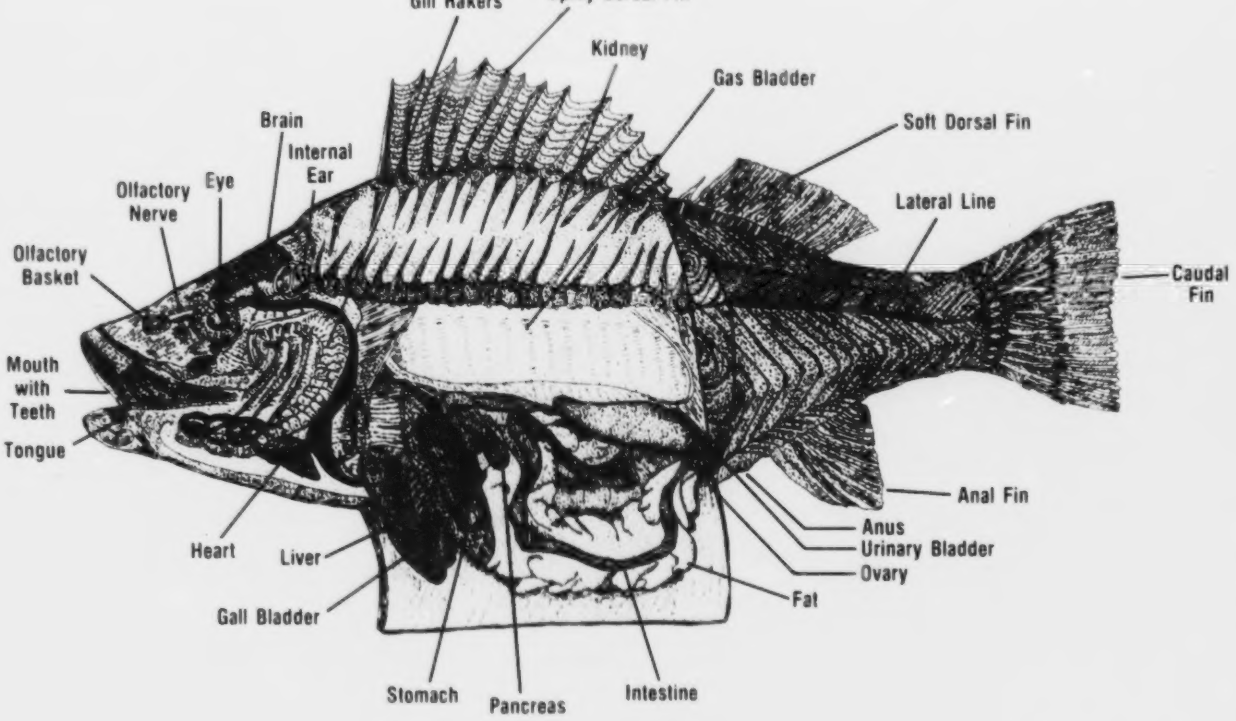
Bony fishes have a gas bladder, unlike sharks, and thus need not perpetually swim to maintain buoyancy. It is believed that the highly advantageous gas bladder of bony fishes developed from primitive lungs of freshwater fish. The most primitive gas bladders today, those which in design and function are similar to primitive lungs, are found in African lungfish. In the African lungfish, a pair of sac-like lungs develops as a ventral outgrowth from the posterior section of the pharynx. These primitive lungs allow the fish to survive periods of drought and stagnant water by permitting direct gas exchange with the atmosphere.

Some present-day freshwater fishes possess gas bladders which function somewhat like primitive lungs, as evidenced by air gulping freshwater fishes, while those bony fishes which invaded the oceans have gas bladders which function primarily as hydrostatic organs. Those bony fishes which reentered freshwater from the oceans in which they developed, like the perch, are the freshwater fishes whose gas bladders function primarily as hydrostatic organs.

A gas bladder is very convenient in a water environment. It is filled with gases similar to those dissolved in the water (nitrogen, oxygen, and carbon dioxide primarily). As it functions hydrostatically, it adjusts the specific gravity of the fish's body so that the fish can stay at different water depths with a minimum of effort. Gases may be secreted into the bladder or absorbed from it through specialized capillary networks in the bladder wall. The gas bladder also may function as a respiratory storage tank under conditions of oxygen deficiency.

The Perch

Modern day bony fishes are divided into two types, fleshy-finned and ray-finned. Fleshy-finned fishes, such as lungfishes, gars, and sturgeons, are the more primitive of the bony fishes. The most successful of the bony fishes are the ray-finned fishes, such as the perch. In this laboratory you will study the external and internal anatomy of a ray-finned fish, *Perca flavescens* (the perch), and relate the structures of the perch to their functions. You will dissect a fish in order to identify and trace the internal organs. Study the figure one drawing below, and refer back to it as necessary, as you proceed with the laboratory.



Gill Rakers
Spiny Dorsal Fin
Kidney
Gas Bladder
Brain
Internal Ear
Soft Dorsal Fin
Olfactory Nerve
Eye
Lateral Line
Olfactory Basket
Caudal Fin
Mouth with Teeth
Tongue
Anal Fin
Anus
Urinary Bladder
Ovary
Heart
Liver
Fat
Gall Bladder
Stomach
Pancreas
Intestine

Female Yellow Perch

Figure 1

Pre-lab

Supplies needed:

Equipment

dissecting pan scissors forceps probe
dissecting scope or magnifying glass

Materials

preserved yellow perch

Special Preparations

Students will find identification of internal organs to be easiest if preserved perch are used rather than fresh or frozen perch. Preserving fluids tend to harden soft tissues.

Time Required

The perch laboratory requires one classroom hour, in addition to preparations, discussion, and review.

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Procedure: Hour 1

Students need all listed supplies.

Steps

A. Place the preserved perch on a dissecting tray, dorsal side up. Identify the following external structures. Those structures not discussed in detail here have functions similar to those of the shark studied in laboratory thirty-five.

- Dorsal and ventral sides.
- Head, trunk and tail: these are the three body segments of vertebrates. The tail of a fish is the caudal fin.
- Ctenoid scales: the rough or spiny fringe on the outer edge of each scale is characteristic of this type of fish scale. There are many scale types, and ctenoid scales are characteristic of perch and bass. Remove a scale from your fish and observe it under a dissecting scope.
- Fins.
- Anus.
- Operculum: bony covering of the gills.
- Lateral line.
- Eye.
- Nostrils: these lead to olfactory sacs which contain semicircular canals and which function as balancing organs.
- Mouth: open the mouth and observe the action of the upper jaw (maxilla) and the lower jaw (mandible). Note the tongue and its attachment in the mouth.
- Teeth.

1. In the space provided below, diagram a scale from your perch as seen under magnification.

Studies of many fishes have revealed that the age of a fish can be determined by examining its scales. The number of scales on a fish remains the same throughout its life, and the scales merely become larger as the fish grows. The growth of the scale is marked by a series of concentric rings. The rings are closer together when formed during autumn and winter, and further apart as they form during the spring and summer when more feeding and growth occur. By counting the number of times the rings are closer together you can know how many winters the fish has lived.

2. How old is your fish? ____________________

3. Describe the teeth of your perch ____________________

____

____

____

4. Do the teeth appear to arise from the dermis of the skin, or from the bony endoskeleton? ____________

5. Are the teeth of your perch similar or different from those of a shark? If they are different, how are they different?

Probe into the mouth cavity (pharynx), at the same time raising the operculum covering the gills.

6. Into what structure does the pharynx lead?

Fish usually breathe by forcing water from the pharynx out over the gills where dissolved oxygen in the water enters the capillaries of the paired gills, and carbon dioxide diffuses from the capillaries of the gills into the water. Not all fish, however, breathe in this manner. For example, a climbing perch gulps air from the surface of the water, and oxygen diffuses into the bloodstream from accessory structures in the pharynx itself.

7. Insert your probe into one of the fish's nostrils. Does the probe enter the mouth cavity? Explain.

B. Cut away the bony operculum from one side of your fish and expose a gill chamber. Carefully remove a gill by cutting the upper and lower attachment of the gill arch, rinse it off, and study its structure under magnification. Locate the capillary gill filaments and the bumpy projections on the gill arch known as gill rakers. Gill rakers prevent coarse materials from entering the spaces between individual gills.

8. What life function takes place in the gill filaments?

C. With a pair of scissors cut through the angle of the jaws all the way to the posterior tip of the operculum. Place a finger in the fish's mouth so as to guide the deeper point of your scissors. Continue the incision posteriorly, cutting parallel to the lateral line, and stop at about two-thirds of the length of the body. Now cut ventrally toward the anus. Carefully fold back the body wall to expose the organs beneath, and gently wash out the body with tap water.

Notice the silvery peritoneum (cavity lining tissue) that lines the coelom, and the sheets of tissue (mesenteries) that cover the organs.

9. What appears to be the purpose of the mesenteries?

Identify the following internal digestive organs:

- Liver: reddish-brown in fresh and frozen fish, cream-colored in preserved fish. Cut the liver free from its attachment to the body and remove it.
- Gall bladder: located on the lower side of the liver.
- Esophagus and stomach: these are exposed with the removal of the liver. Open the stomach to determine if the contents were undigested at the time of death.

- Pylorus: where the stomach and intestine join. Small, pouch-like structures extending from the pylorus are called pyloric caeca. The pyloric caeca function in the secretion of digestive chemicals and also aid in the absorption of digested materials.
- Intestine: follow the intestine to the anus. It may be necessary to remove fat from the fish in order to trace the intestine.

10. How many lobes does the liver of a perch have?

11. How many pyloric caeca does your perch have?

The dorsal portion of the body cavity is occupied by a very large, thin-walled sac known as a gas bladder. It may have been broken when you removed the fish's body wall; if so, you only will be able to observe the space the bladder occupied.

12. What is the function of the gas bladder?

Dorsal to the gas bladder are small dark masses of tissue along the spine. These are the kidneys. Two urinary ducts lead away from the kidneys and then unite and drain into the urinary bladder. Urine is expelled through the urogenital opening which is immediately posterior to the anus.

D. Remove the digestive organs from your perch by cutting the tract at the esophagus and just above the anus. Also remove any obvious fat. This should expose the fish's gonads.

Identify the reproductive organs:

- If your fish is a female, she will have an ovary. Ovaries are large and yellowish. They contain many eggs, known as roe.
- If your fish is a male, he will have testes in the same location. Testes are smaller than the ovary, and creamy white in preserved specimen.
- Thread-like ducts lead from the gonads to a tube joining the urinary bladder to the urogenital opening. Usually, fertilization in bony fishes is external.

13. The size of the gonads varies seasonally. Why might this be?

14. Can you estimate the time of year that your perch was killed by the size of its gonads? How or why not?

Both the fish heart and brain are very difficult to expose clearly. Your instructor may wish to grant extra credit to students who are able to accomplish this task.

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Resources

Kenney, William R. *Fishes and Their Morphological Diversity.* #446 filmstrip, available from Educational Images, Ltd.

Wassink, Jan L. and Charles R. Belinky. *Survey of the Animal Kingdom: The Vertebrates, part I: "Urochordates and Craniata (Vertebrata) - Through Fish."* #FS 1059 filmstrip, cassette, and guide, available from Educational Images, Ltd.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

ctenoid scale
gas bladder
operculum
Osteichthyes
Perca flavescens
pyloric caeca

Review

36. Perch

Name______________________________

Date______________________________

Multiple choice

______ 1. The part of the gill in which gas exchange takes place is the
a. slit
b. arch
c. raker
d. filament

______ 2. Paired dark structures along the spinal column on the roof of the body cavity are called
a. ovaries
b. testes
c. kidneys
d. gall bladder

______ 3. A folded membrane that connects the intestine to the dorsal body wall is a
a. vas efferens
b. pancreas
c. mesentery
d. nictitating membrane

______ 4. The following part of a gill of the perch serves as a filter and keeps hard particles out of the gills:
a. arch
b. filament
c. branchiae
d. raker

______ 5. The scales of *Osteichthyes* are
a. placoid
b. dermoid
c. ctenoid
d. dentoid

______ 6. The outer protective covering of the perch gill is the
a. gill plate
b. operculum
c. notochord
d. opicula

______ 7. A perch has one, and a shark does not.
a. dorsal fin
b. gas bladder
c. eyelid
d. gall bladder

______ 8. The age of a fish may be determined by
a. measuring its length
b. counting the spines on its caudal fin
c. counting its teeth
d. counting the close rings on its scale

______ 9. This organ functions in the secretion of digestive chemicals, and also aids in the absorption of digested materials.
a. pharynx
b. pyloric caeca
c. large intestine
d. mouth

______ 10. Roe are expelled through a female fish's
a. anus
b. operculum
c. urogenital opening
d. pharynx

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Arrange the following digestive organs in order, A through E, starting from the mouth.

______ 11. anus

______ 12. pharynx

______ 13. intestine

______ 14. stomach

______ 15. pylorus

37. Laboratory

Frogs

When you have completed this laboratory you should be able to:

1. Understand the structures and life cycle of amphibians.
2. Identify the structures of a frog and relate them to their functions.
3. Identify the organ systems of a frog.

Class *Amphibia*

Amphibians, or "dual-lived" animals, first emerged during the Devonian period, a time of great climatic changes. It is believed that the primitive lungfishes (see laboratory thirty-six) were the transitional life form between true fishes and amphibians. Amphibians — frogs, newts, and salamanders — are the earliest and most primitive of all animals which can live on land. At the same time, however, they never completely became free of a water environment. They must return to water to reproduce. Without water their soft, jelly-like eggs dry out and die. Even most adult amphibians cannot travel far from water, because they must keep their skin moist.

In prehistoric times there were many amphibians, both large and small. Today only three small orders remain. The order *Apoda* contains the few surviving legless amphibians of the tropics. These creatures superficially look like worms. The order *Caudata* contains all legged amphibians which retain their tails as adults, such as newts and salamanders. The order *Salienta* contains all legged amphibians which lose their tails as adults, such as toads and frogs. Amphibians usually live as aquatic herbivores when larvae and as terrestrial or semi-aquatic carnivores when adults. They are aptly named, living a two-phased life in two different environments.

The Frog

In this laboratory you will study the external and internal organs of a common amphibian, *Rana pipiens*, the leopard frog. The frog is a good representative of the amphibians, and, in its adult form, many of the organs are placed in the body similarly to humans. Thus, in dissecting the amphibious frog, you also will be increasing your knowledge of mammalian anatomy.

Pre-lab

Supplies needed.

Equipment

dissecting pan
scissors
scalpel
forceps
probe
dissecting pins
dissecting scope or magnifying glass

Materials

preserved frog

Special Preparations

None.

Time Required

The frogs laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Place the preserved frog on a dissecting tray, dorsal side up. Identify the following external structures.

- Dorsal and ventral sides.
- Head and trunk: most vertebrate terrestrial animal bodies have four regions, a head, neck, trunk, and tail. However, the frog loses its tail during the change from larva to adult (metamorphosis), and a neck is not obvious.
- Anus.
- Forelegs (pectoral appendages) and hindlegs (pelvic appendages): the powerful hindlegs are the primary means of locomotion, and the forelegs simply support the front part of the body. Count the digits on both a foreleg and a hindleg. Notice that the first digit, or thumb, is missing on a foreleg, and that, if you have a male frog, the middle digit is stouter than the other digits. This middle digit helps the male frog clasp the female during copulation. Notice also webbing between the toes and the lack of fingernails and toenails.
- Tympanic membrane: this lies posterior to each eye. This is a round eardrum.
- Eyes: notice the position of the eyes on the head, and also the presence of eyelids. The upper eyelid is a simple skin fold, and the lower eyelid is a translucent membrane called the nictitating membrane. When the eyeball is retracted into the eye socket for protection while swimming, the lower lid spreads over its surface.
- Brow spot: this is found between and in front of the eyes on top of the head. It is a lighter colored spot about the size of a pinhead, and it is a vestige of the median eye of very primitive vertebrates.
- Nostrils: these are dorsal to the front of the mouth.
- Mouth: cut the mouth at each hinge joint to permit opening the mouth wide.
- Tongue: in the mouth. Determine its attachment and shape. Remember that preserving fluid causes tissues to harden and that in death the tongue has lost its flexibility.
- Glottis: a slit-like structure in the center-rear of the mouth. Use a probe to determine where the glottis leads.
- Vocal sac: this is found only in males. The opening to the vocal sac may be found near the hinge of the lower jaw on either side of the mouth.
- Eustachian tubes: the openings to the eustachian tubes are located near the hinge of the upper jaw.
- Internal nostril openings: these are located in the roof of the mouth.
- Teeth: the two large teeth extending from the roof of the mouth are called vomerine teeth.

1. Describe the attachment of your frog's tongue. ______________________________

____

____

2. In a living frog, the tongue is sticky. What are the advantages of this feature? ______________

____

____

3. Account for the extreme width of the esophagus opening near the glottis. ______________

____

____

4. Where do the eustachian tubes lead? ______________________________

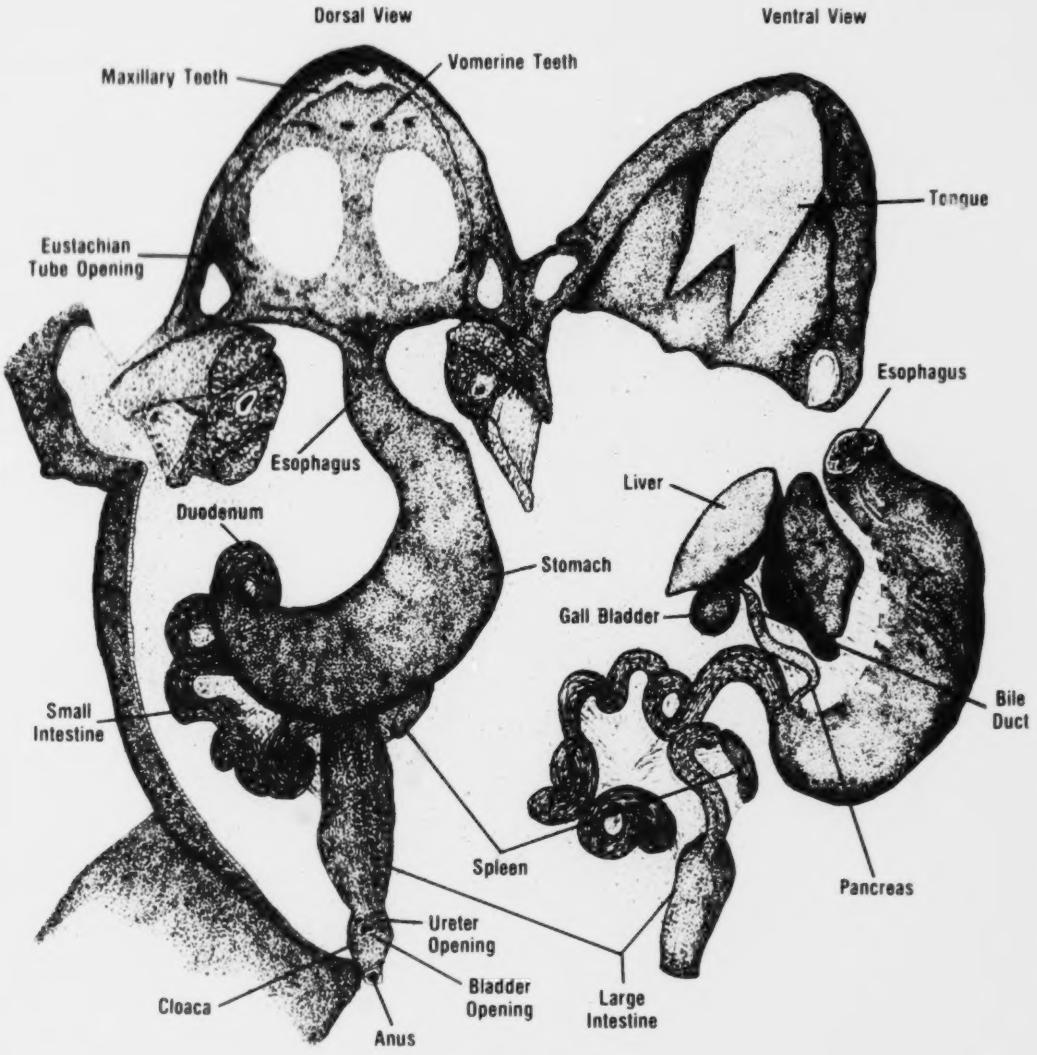
5. Where do the internal nostril openings lead? ______________________________

6. How can the position of both the eyes and the nostrils be considered adaptations of a frog in water? ____

7. What is the function of the two vomerine teeth? ____

8. Which of the jaws is provided with small teeth, upper or lower? ____

A frog has all the body systems common to man. Study the figure one diagram below as you examine the digestive, circulatory, and respiratory systems of your frog. Refer to the illustration as necessary during your dissection.


Dorsal View
Ventral View
Maxillary Teeth
Vomerine Teeth
Tongue
Eustachian Tube Opening
Esophagus
Esophagus
Liver
Duodenum
Stomach
Gall Bladder
Bile Duct
Small Intestine
Spleen
Pancreas
Ureter Opening
Bladder Opening
Cloaca
Anus
Large Intestine

Frog Digestive System

Figure 1

B. Lay the frog on its dorsal side. Insert your scissors through the skin just above the anal opening and make an incision in the skin up the belly of the frog to the jaw. Make lateral incisions off this first incision along both the pelvis and pectoral regions of the body to the legs. Fold the flaps of skin back to reveal the underlying muscles. Observe the striated muscles thus exposed, and also the large abdominal vein lying along the midline under the muscle layer.

Muscular System

Frogs have musculature similar to mammals. Striated muscles are for movement, and they shorten as they contract. All internal organs, excepting the heart, have smooth muscles which operate involuntarily. The heart is composed of cardiac muscle, which is intermediate between striated and smooth muscle tissue.

9. Where does the abdominal vein lead? ______________________________

10. From the pattern of striations observed in your frog's muscles, how might they function in the living frog?
____
____
____
____

C. Repeat the same incisions you made in cutting the skin, this time going deeper to cut through the muscles. Cut through the bones of the pectoral girdle and remove the muscle layers with forceps. Pin back the muscles and skin in order to expose the organs underneath. Identify the following internal structures and organs.

Digestive System

- Pharynx: this is a small area back of the apparent mouth cavity where both food and air passages cross.
- Esophagus: this tube connects the pharynx to the stomach.
- Stomach: the anterior end of the stomach is larger than the esophagus it adjoins. Using scissors, cut the stomach out of your frog. Cut along the outer stomach curvature toward the pylorus, and pin the tissue of the stomach back in order to examine any contents which may be present. Study the stomach lining and contents under magnification.
- Mesentery: these tissues hold the organs of the coelom in place.
- Pylorus: this is also known as a pyloric sphincter, because it is a muscular constriction which separates the posterior end of the stomach from the beginning of the small intestine.
- Duodenum: this is the anterior, short end of the small intestine which receives secretions from both the liver and pancreas. Cut a small section of the duodenum and observe it under magnification.
- Ileum: the lower, highly coiled end of the small intestine.
- Liver: a large gland which nearly covers the anterior end of the body cavity. The liver secretes bile, which emulsifies fats and aids in their absorption by the body. The liver also aids in determining the concentration of glucose and certain other constituents of blood. Hepatic ducts from the liver take the bile to be stored in the gall bladder, and the gall bladder delivers the bile to the duodenum as needed through the bile duct.
- Gall bladder: a greenish round bile storage organ found on the underside of the liver.
- Pancreas: a large gland which produces a variety of enzymes important in the digestion of food, as well as insulin and glucagon. The pancreatic duct discharges these enzymes into the common bile ducts, which then deliver them to the duodenum.
- Large intestine: this is also known as the colon. Digestion is completed in this intestine, with the last nutrients being absorbed into the circulatory system.
- Cloaca: a common chamber which receives the products not only of the digestive system, but also of the excretory and reproductive systems. From the cloaca these materials pass out the anus.

11. How many lobes does your frog's liver have? ______________________________

12. What is the function of the liver and gall bladder?

13. Was there any undigested food in your frog's stomach? If so, what? Also, describe the lining of the frog's stomach.

14. What is the function of the mesentery?

15. Describe what you observed when you removed a piece of the small intestine and examined its lining under magnification.

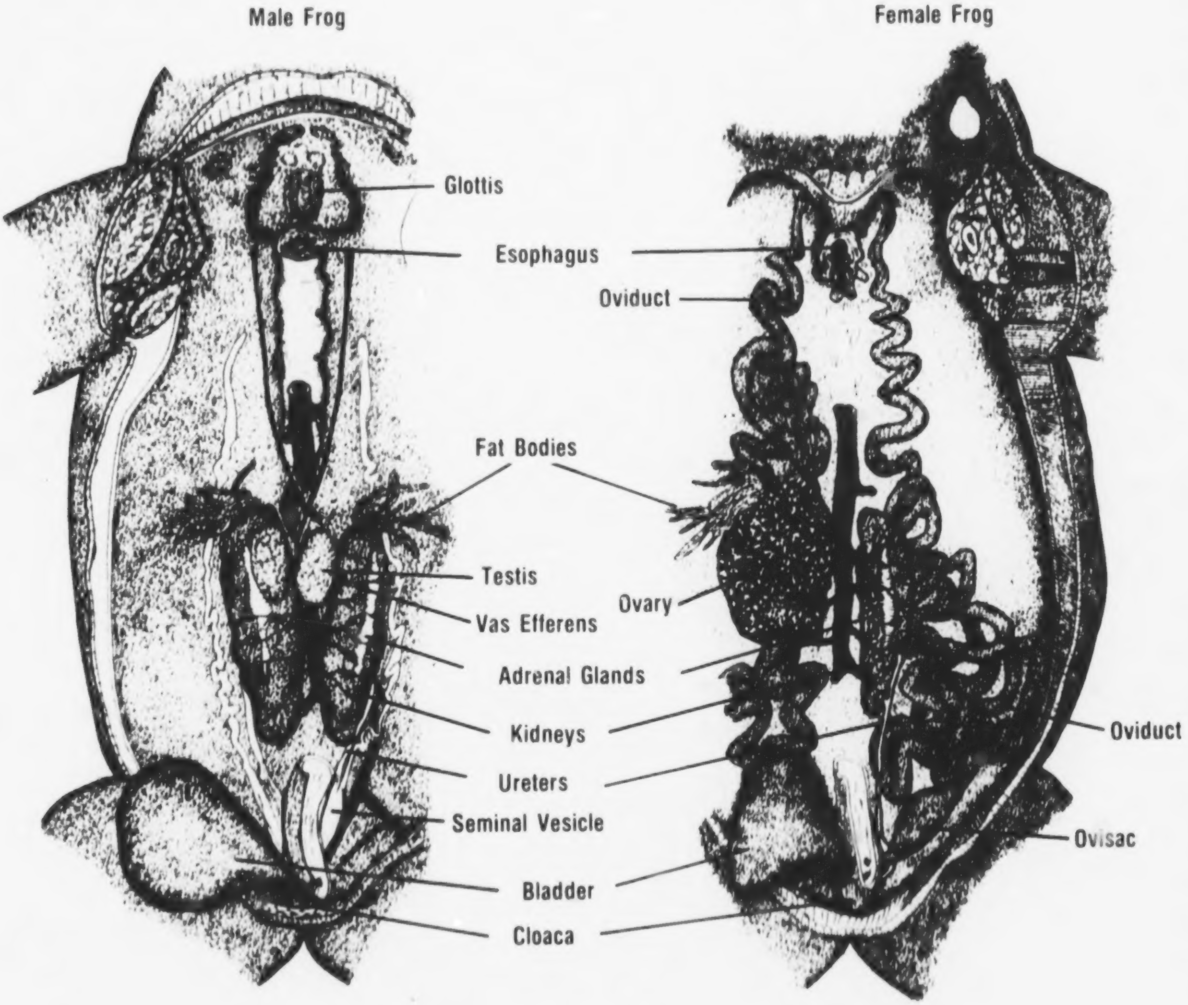
Now you will identify some organs of the circulatory and respiratory systems.

Circulatory and Respiratory Systems

- Heart: it consists of a series of chambers which force the blood along and valves that prevent backflow. The heart is found in a thin membranous sac called the pericardium in a pericardial cavity. Two auricles (atria) form the wider anterior region. They are readily recognized by their thinner walls and darker color. There is one ventricle which is the conical posterior portion of the heart. It has thick walls. On the dorsal side of the frog heart you will see a thin-walled sac called the sinus venosus. It is formed by three stout veins called vena cavae, and it passes blood into the right auricle. On the ventral side of the frog heart you will see the truncus arteriosus, a stout cylindrical vessel which arises from the base of the ventricle at its right side.
- Lungs: these relatively small sacs actually account for very little of the frog's respiratory activity. Most oxygen/carbon dioxide exchange occurs by simple diffusion through the moist frog skin. The lungs function when the frog gulps in air, because the frog does not have a diaphragm, or other structure to function as a billows to pump air in and out of the lungs. When the frog is hibernating (winter sleep) or estivating (summer sleep) at the bottom of a pond, all respiration is through the skin.
- Spleen: blood cells are produced, stored, and destroyed in this organ. It is a small, spherical organ which is located in the mesentery of the digestive tract.

16. In the space provided below draw both a front and back view of the frog heart. Label the structures in your drawings.

Study the figure two diagram below as you investigate the reproductive and excretory systems of your frog. Refer to it as necessary during your dissection.


Male Frog
Female Frog
Glottis
Esophagus
Oviduct
Fat Bodies
Testis
Vas Efferens
Ovary
Adrenal Glands
Kidneys
Oviduct
Ureters
Seminal Vesicle
Ovisac
Bladder
Cloaca

Frog Reproductive Systems

Figure 2

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D. Remove the organs of the digestive, respiratory, and circulatory systems in order to provide a better view of the reproductive and excretory systems of your frog. Also remove obstructing fat. Some frogs will have fat bodies which practically cover the entire coelom, while other frogs will have few, if any. If your frog is a female filled with mature eggs (thousands of black spheres), you also will need to remove the eggs in order to see the remaining organs of her reproductive and excretory systems. Identify the following internal organs and structures.

Female Reproductive System

- Ovaries: their size will vary depending upon the maturity and also the time of year the frog was killed. The ovaries may be filled with eggs. Also locate the oviducts, or cream-colored tubes, through which eggs pass from the anterior of the body cavity to the cloaca. The bulges at the end of the oviducts just before entering the cloaca are called ovisacs.

Male Reproductive System

- Testes: these are in the same position in the male frog as ovaries are in the female, that is, lying on top of the kidneys. Minute ducts called vas efferens transfer the sperm produced in the testes to seminal vesicles, slight bulges in the Wolffian ducts, for storage. Wolffian ducts, as well as other kidney tubules, thus have a dual function, transport of both urine and sperm, in the male frog.

Frog reproduction is external, and during mating, the male frog employs his forelimbs to embrace the female frog about her trunk. This embrace is called amplexus, and it forces the female to lay her eggs in water as the male sheds his sperm. As the eggs are laid, the protective layers of jelly imbibe water and swell.

E. Remove your frog's reproductive system, in order to clearly see the excretory system. Identify the following structures.

Excretory System

- Kidney: the skin and lungs remove some wastes, but the kidneys are the major excretory organs of vertebrates. The kidneys lie next to the vertebrae in a membranous sac. Arteries and veins feed into and out of the kidneys, and at their posterior ends tubes called Wolffian ducts carry the urine produced in the kidneys to a urinary bladder for eventual discharge from the body. Wolffian ducts function in the same way as ureters do in higher vertebrates, but structurally they are not the same. Lying on top of the kidneys are small adrenal glands, which produce adrenalin, and they are part of the hormonal system of a frog.

17. Is your frog a male or female? ______

18. What are the functions of Wolffian ducts? ______

19. Complete the review chart, figure three below, by filling all squares with key words. The "simplest animal to have" line asks you to name those structures or functions which that animal is the first to have. (Similar review charts appear in laboratories thirty and thirty-three.)

Review	Shark	Perch	Frog
Phylum			
Class			
Genus			
Locomotion			
Habitat			
Digestion			
Excretion			
Respiration			
Nervous System			
Skeleton			
Skin & Structures			
Reproduction			
Simplest Animal to Have			
Other Members			

Figure 3

Resources

Blaustein, Andrew R. and Richard K. O'Hara. "Kin Recognition in Tadpoles," *Scientific American*, January 1986.

Educational Dimensions. *Dissection: Frog*. #52-4937, one filmstrip with cassette.

Feder, Martin E. and Warren W. Burggren. "Skin Breathing in Vertebrates," *Scientific American*, November 1985.

Wassink, Jan L. and Charles R. Belinky. *Part II: Amphibians and Reptiles*. #FS 1059, filmstrip, cassette, and guide, available from Education Images, Ltd.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- adrenal gland
- amphibian
- amplexus
- cloaca
- duodenum
- estivation
- hibernation
- ileum
- nictitating membrane
- *Rana pipiens*
- spleen
- vomerine teeth
- Wolffian duct

Review

37. Frogs

Name______________________________

Date______________________________

Multiple choice

______ 1. Teeth in the roof of a frog's mouth are known as the
a. vomerine teeth c. mandibular teeth
b. maxillary teeth d. pharyngeal teeth

______ 2. The tympanic membrane in the frog
a. covers the eye c. serves in respiration
b. supports the intestines d. covers the ear

______ 3. Amphibian means
a. double appendage c. double life
b. double nerve cord d. double vision

______ 4. The frog has
a. two auricles and one ventricle
b. two auricles and two ventricles
c. one auricle and one ventricle
c. one auricle and two ventricles

______ 5. Salamanders and newts belong to the order
a. *Apoda* c. *Salienta*
b. *Caudata* d. *Wombatia*

______ 6. The pyloric sphincter lies between the
a. ileum and duodenum c. duodenum and stomach
b. ileum and stomach d. stomach and esophagus

______ 7. The storage area for feces in the frog is the
a. bile duct c. large intestine
b. pancreas d. cloaca

______ 8. If the frog damaged its eustachian tubes, it would have difficulty
a. seeing c. hearing
b. smelling d. tasting

______ 9. Which of the following has nothing to do with digestion?
a. gall bladder c. adrenal gland
b. pancreas d. liver

______ 10. The structure on the ventral surface of the kidney is the
a. ureter c. adrenal gland
b. posterior vena cava d. renal vein

______ 11. A frog can see easily under water because of a
a. tympanic membrane
b. olfactory tract
c. nictitating membrane
d. eustachian tube

______ 12. Which of the following structures double in function in the male frog?
a. seminal vesicle
b. vas efferens
c. Wolffian duct
d. ureter

______ 13. Sexual stimulation by the male frog, which causes the female to release her eggs, is known as
a. amphioxus
b. amplexus
c. amphibious
d. amphitheater

______ 14. A folded membrane that connects the intestine to the dorsal body wall is the
a. vas efferens
b. pancreas
c. mesentery
d. nictitating membrane

______ 15. Estivation is
a. the type of reproduction seen in the frog
b. a period of winter inactivity
c. a means of locomotion
d. a period of summer inactivity

______ 16. Amphibians are not completely free of the water environment because of their
a. feeding habits
b. means of locomotion
c. circulatory system
d. reproductive requirements

______ 17. The digestive, reproductive, and excretory systems of the frog open into the common chamber called the
a. sinus venosus
b. kidney
c. cloaca
d. urinary bladder

______ 18. Only male frogs have
a. a glottis
b. a cloaca
c. an esophagus
d. a vocal sac

______ 19. The hindlegs of a frog emerge from the
a. pectorals
b. vertebrae
c. pelvis
d. cranium

______ 20. What organ produces bile?
a. gall bladder
b. adrenal glands
c. pancreas
d. liver

38. Laboratory

Pigs

When you have completed this laboratory you should be able to:

1. Understand some structures and life cycles of mammals.
2. Identify external and oral structures of a pig and relate them to their functions.

Class *Mammalia*

Mammals, or those animals with breasts, include not only cats, mice, pigs, and elephants, but man as well. There are many orders and sub-groupings of mammals, but they all share certain characteristics, foremost of which is the presence of mammary glands with which they feed their young. Another common trait is the presence of hair. The most intelligent of all animals, mammals reflect a high degree of complexity, both in terms of structure and of behavior.

Mammals also differ from most other animals by being more active and devoting greater care to their young. Only birds have a higher activity level than mammals. Both birds and mammals care for their young and are active, warm-blooded animals, but it is in intelligence, specifically development of the cerebrum, that mammals differ most strikingly from the birds and other animals.

Temperature Control

An active life style requires a high and rather constant rate of metaboblism; hence, all mammals and birds are homotherms, or warm-blooded. Homotherms require some form of covering to keep heat in or cold out; birds have feathers and mammals have hair. These structures entrap air and reduce heat loss by insulating the skin. In mammals, when the surrounding temperature drops, tiny muscles associated with the hairs contract, pull them more erect, and increase the effective thickness of the insulating layer. Heat production in both mammals and birds also may be increased by shivering.

Heat is dissipated, when necessary, by an increased blood flow through the skin and by the evaporation of water. Most mammals lose water from the body surface by sweating, but if the mammal has few sweat glands, it must pant. Dogs, for instance, "sweat" by panting and evaporating water from their tongue and respiratory passages. Birds lack sweat glands, but they evaporate water from their respiratory tract.

Teeth and Diet

Mammals occupy many niches in nature and have developed teeth able to handle a wide variety of foods. Some mammals are carnivores, or meat eaters, some are herbivores, or plant eaters, and some are omnivores and can eat just about anything organic. Man, bears, raccoons, and pigs are examples of omnivores.

Breathing and Activity

Increased activity must be accompanied by increased ability to respire. Mammals thus have highly developed respiratory systems, with large increases, compared to other vertebrates, in the number of air passages inside the lungs, and a greatly increased blood system feeding into those respiratory passages. It is estimated that the respiratory surface of a human's lungs is thirty to fifty times the surface area of the body that houses the lungs.

Also, mammals have a diaphragm, a muscular structure whose contractions, together with a forward movement of the ribs, expand the chest cavity and draw air into the lungs. Finally, mammals have a secondary palate, or bony plate called the soft palate, in their mouths which separates breathing and eating functions. Mammals can breathe continuously, except during the act of swallowing.

Movement

Mammals, like birds, show greater agility than lower vertebrates. The appendages of four-legged mammals extend directly down to the ground in a vertical plane, instead of out from the body in the horizontal plane, as the first segment of the limb does in amphibians and most reptiles. Increased intelligence also impacts animal movement, in that increased movement with quicker responses is possible.

Mammalian Orders

The first mammals were probably small animals which appeared during the Mesozoic era, or the age of the dinosaurs. Their fossils are distinguished from those of extinct mammal-like reptiles by certain bony characteristics, such as three auditory bones within the middle ear and a specialized jaw joint in the face. Today there are three distinct mammalian subclasses within *Mammalia*. These subclasses are grouped by differences in reproductive processes, that is, those that reproduce by egg-laying processes, those that employ both a yolk for nourishment and a placenta for attachment, and those with a true placenta that both attaches and feeds the fetus. True placental mammals are the most successful and encompass sixteen orders.

Monotremes

Monotremes represent one subclass of mammal, the egg-laying mammal. There are just a few species of monotreme alive today, such as the duck-billed platypus and the spiny anteater. The duck-billed platypus lays two or three eggs in a nest, after which the mother incubates them. Spiny anteaters lay two eggs at a time, and incubate the eggs in a special brood pouch on the lower side of the mother. Both animals are native to Australia and New Guinea and feed their young with milk.

Marsupials

Another subclass of mammal is the marsupial, the pouched mammal. These mammals reproduce by retaining fertilized eggs inside the mother's body only during early stages of development. Although the fetus is attached to the uterus by a placenta, all nourishment is provided by the egg yolk. When the egg yolk has been consumed, the immature baby is expelled. It must crawl, using its front legs, from the genital opening into a pouch on the abdomen of the mother's body, where it attaches itself to a mammary gland for final stages of development. Most marsupials are native to Australia and New Guinea, although some, like the North American opossum, have survived on other continents. Kangaroos, wallabies, koala bears, and wombats are examples of Australian marsupials. Two carnivorous marsupials have been found on the southern Australian island of Tasmania, the Tasmanian Wolf, believed to be extinct, and the rare Tasmanian Devil.

Placental Mammals

The third subclass of mammal, those with a true placenta, is by far the most successful and numerous of all mammalian types, representing over ninety-five percent of all mammal species alive today. In the placental mammal both embryonic and fetal growth take place within the female's uterus. The embryo and fetus are attached to the uterine wall, and a placenta, which supplies oxygen and nutrients to the unborn, attaches to the fetus. The uterus of the placental mammal protects the young during a long period of development.

The order of insect-eating mammals (*Insectivora*) is probably the most primitive of all placental mammals. They include shrews and moles. They have small brains and primitive teeth. There are also flying mammals (bats), gnawing mammals (beavers, gophers, and rats), rodent-like mammals (rabbits and pikas), toothless mammals (armadillos, sloths, and anteaters), aquatic mammals (whales, dolphins, and porpoises), trunk-nosed mammals (elephants), carnivores (lions, wolves, bears, and seals), hoofed mammals called ungulates (goats, horses, cows, pigs, deer, elk, moose, and antelope), and primates (apes, monkeys, and man). Primates, or erect mammals, have the most highly developed brains of all living organisms.

Sus scrofa

The pig, *Sus scrofa*, is a member of a group of mammals known as even-toed ungulates. These animals have only two of the original five digits of their mammalian ancestors. The first toe has been lost and the second and fifth toes are reduced in size or lost. The two primary toes form the hoof (in the uneven-toed ungulates, such as horses and zebras, the hoof is composed of three toes). Ungulates are all hoofed herbivores, many of which are horned. Taxonomically, the pig belongs to the phylum *Chordata*, class *Mammalia*, order *Artiodactyla*, genus *Sus*, and species *scrofa*.

The pig is an excellent representative for mammalian anatomical studies, because the organs and systems of the omnivorous pig are similar to those of the omnivorous human.

In this laboratory you will study the external and mouth structures of a fetal pig. A fetal pig is an unborn pig usually obtained from a pregnant sow slaughtered for meat. The period of gestation, or development within the uterus of the female, is 112 to 115 days, with seven to twelve piglets in a litter. Fetal pigs obtained from biological suppliers can vary between twenty to thirty centimeters in length, with the developmental age of the fetal pig ranging between one hundred days to nearly full term in larger specimens.

The fetuses are removed from the uterus, cooled immediately, and then embalmed through one of the umbilical arteries. Liquid red latex is injected under pressure into the arterial system and also through one of the umbilical arteries. Blue latex is similarly injected into the venous system through the external jugular vein. The latex solidifies inside the arteries and veins, and it allows one to more easily identify the extent and components of the animal's circulatory system.

Fetal pigs not only illustrate the basic anatomy of adult mammals, but they also provide information about certain features and structures of the mammalian fetus. They, however, do not have fully formed and differentiated muscular and skeletal systems. Because fetal pigs are mammals, with all the complexities of form and function that mammals possess, their dissection will occupy several laboratory hours.

During this laboratory you will study only the external structures of a fetal pig and then dissect and study its mouth structures. You will keep the same specimen for use in four subsequent laboratories in which you will dissect and study the digestive, circulatory and respiratory, excretory and reproductive, and nervous/sensory systems of the fetal pig.

Pre-lab

Supplies needed:

Equipment

dissecting pan
scissors
bone shears
forceps
probe
scalpel
dissecting scope or magnifying glass

Materials

preserved fetal pig
plastic bag and tie
string
masking tape

Special Preparations

1) Fetal pigs may be purchased from any biological supply house. Purchase the largest size available, and only those which are double injected, that is, injected with both red and blue latex. If the arteries and veins are not identified in this manner, they are very difficult for the beginning student to distinguish from nerves.

2) The plastic bag should be large enough to contain the fetal pig. The pig used in this laboratory is also used in laboratories thirty-nine, forty-one, forty-three, and forty-five, and the pig may be stored between laboratories in the plastic bag.

3) Disposable gloves are optional.

Time Required

The pigs laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Place the preserved pig on a dissecting tray. Identify the following external structures.

- Ventral and dorsal body.
- Head, neck, trunk, and tail.
- Umbilical cord.
- Anus.
- Ears: the flaps of tissue surrounding the ears are called pinnae.
- Eyes: note the upper and lower eyelids.
- Mouth.
- Nostrils.
- Forelimbs: note that the first toe of both the forelimbs and hindlimbs is missing and that the second and fifth digits are reduced in size. The third and fourth digits form a hoof, and the weight of the body is borne on the tips of those digits. This type of locomotion is called unguligrade. The wrist lies just above the digits. Also identify the elbow, the shoulder, and the scapula, or shoulder blade.
- Hindlimbs: identify the hoof, the ankle, the knee, and the hip.
- Sex: identify the sex of your animal. The male has a swelling, the scrotal sac, at the caudal end of the body between the upper ends of the hindlegs. The male also has a long muscular tubular structure called a penis, which in a fetal pig lies under the skin and which proceeds caudally from a urogenital opening just behind the umbilical cord. The female has a urogenital opening immediately ventral to the anus. A small fleshy genital tubercle projects from the urogenital opening. Both male and female have five to seven teats in two rows on the ventral surface of the abdomen.

1. Is your pig a male or female? How can you tell? ______________________________

____

____

2. How many teats does your pig have? ______________________________

3. In the space provided below, draw a side view of your fetal pig with the external structures labeled.

B. Remove the skin and muscle layer from one side of the face and neck to expose a large, rather dark triangular gland, the parotid. Also expose the mandibular (submaxillary) and sublingual glands.

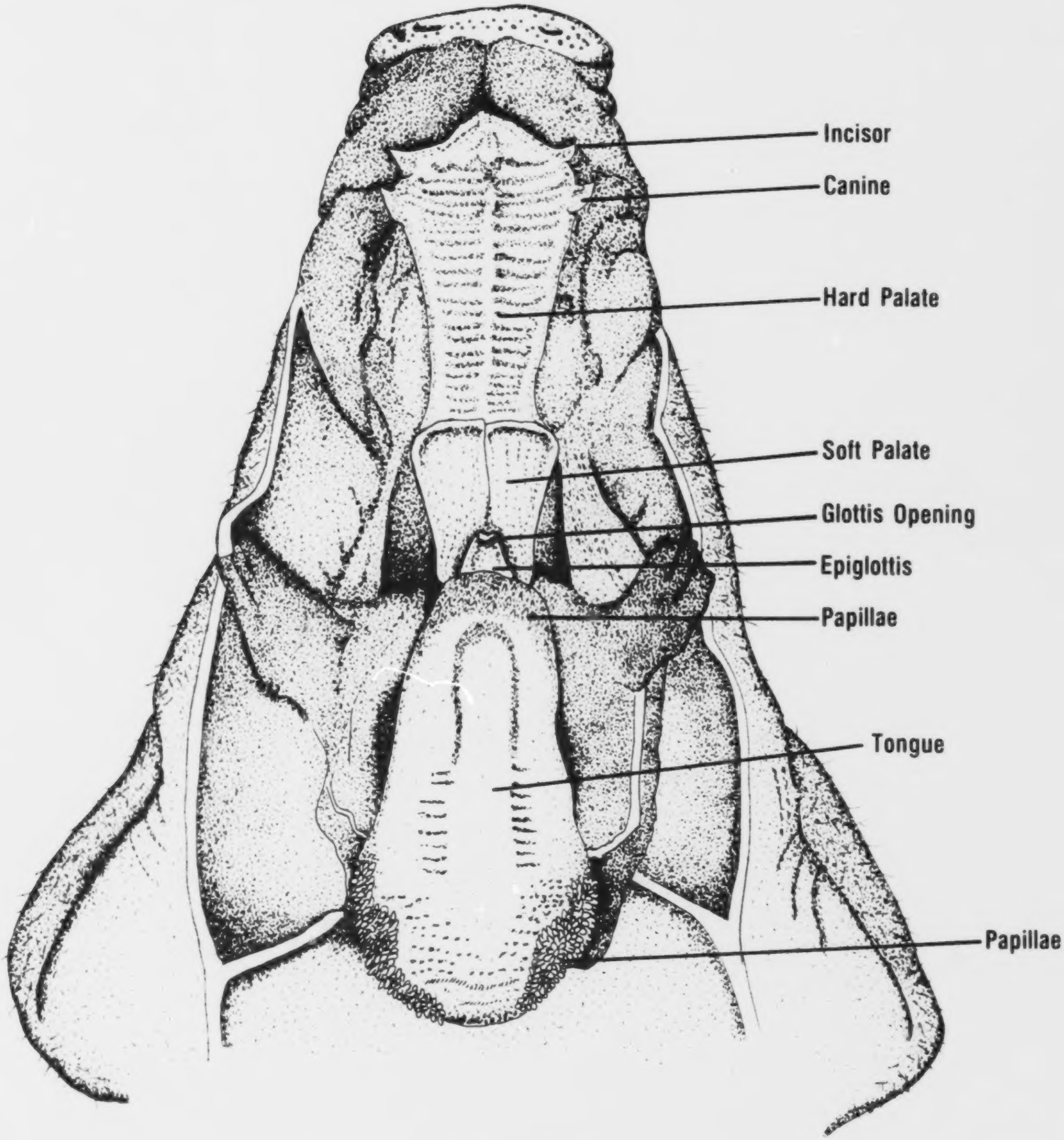
The differentation between muscle tissue and glandular tissue is the presence of fibers in muscle, whereas glands appear to be composed of many small nodules. The muscle which controls the lower jaw is called the masseter, and it is similar in size and shape to the parotid gland. Use a dissecting scope or magnifying glass while you carefully cut. Magnification will help distinguish between muscle and gland tissue. Have your instructor check your work.

Identify the following salivary glands.

- Parotid gland: lies just ventral to the base of the ear, and extends to the caudal border of the masseter muscle (the lower jaw muscle). The duct that drains it is the parotid duct, which arises from the upper part of the gland on its ventral surface. The duct is difficult to identify. It proceeds ventrally around the lower edge of the masseter and opens into the mouth cavity near the upper fourth premolar tooth. The parotid gland secretes a watery fluid as well as enzymes which initiate carbohydrate digestion (see laboratory seven).
- Mandibular gland: lies just caudally to the masseter muscle and is partially covered by the cranial portion of the parotid gland. It is large and somewhat lobed. Also locate the mandibular duct which arises from the cranial edge of the gland, proceeds forward, and opens onto the floor of the pig's mouth. The mandibular gland secretes a viscous digestive fluid.
- Sublingual gland: the caudal part of this gland surrounds a portion of the mandibular duct. It is a long and slender gland whose duct also opens onto the floor of the mouth. The sublingual gland also produces a viscous digestive fluid, as well as enzymes.

4. In the space provided below, draw the side of your pig's head and label the structures and glands found there.

C. Use bone shears to cut back through the corners of the mouth on both sides. Continue the cut through the masseter until the lower jaw can be dropped and the interior of the mouth examined. Identify the structures of the mouth cavity listed after the diagram provided in figure one.


Incisor
Canine
Hard Palate
Soft Palate
Glottis Opening
Epiglottis
Papillae
Tongue
Papillae

Interior of Mouth

Figure 1

- Vestibule: the area between the gums (with teeth in older fetuses) and the lips.
- Tongue: it is attached to the floor of the mouth by the frenulum linguae, a membrane. Note the papillae, or bumps of flesh on the tongue, which house the animal's taste buds.
- Teeth: pigs, like all mammals, possess the following types of teeth: incisors for cutting, canines for tearing, and premolars and molars for chewing and grinding. Baby animals contain deciduous, or baby teeth. Your fetus may or may not have all its baby teeth in evidence. Cut through the gums if necessary to find your pig's teeth. Older fetuses should have thirty-two teeth, none of which are molars. Adult pigs have forty-four teeth, the molars being added with an increase in size.

- Hard palate: this is composed of bone and covered with a ridged mucous membrane.
- Soft palate: slit this to reveal the nasopharynx, or area where the nose and throat cavities join.
- Isthmus of the fauces: this is the opening of the mouth into the pharynx.
- Esophagus: a soft muscular tube lying on the dorsal side of the trachea. Slit the esophagus, insert a probe into it, and run the probe back up into the mouth and note the place (called the esophageal opening) where it emerges.
- Glottis: the opening of the trachea. The small white piece of cartilage on the glottis is called the epiglottis.
- Eustachian tubes: the openings to these tubes are found one or more centimeters caudal to the junction of the soft palate with the hard palate. These tubes connect the middle ear cavity with the nasopharynx.

5. List the number of incisors ________, canines ________, and premolars ________ in your pig's mouth.

D. Place your fetal pig in a plastic bag with enough water to keep it moist. Tie the bag securely and place it back into the dissecting pan. Label the pan with your name and/or your group name, as well as today's date. Store the pig as well as your dissecting equipment for use in laboratory thirty-nine.

Resources

Heller, H. Craig, Larry I. Crawshaw, and Harold T. Hammel. "The Thermostat of Vertebrate Animals," *Scientific American*, August 1978.

Larousse. *Animal Life Series Survey Set.* #175 W 0502, slides with printed narrative, available from Ward's Biology.

Romer, Alfred. *The Vertebrate Story*, 4th ed. University of Chicago Press: Chicago, 1971.

Schoolmasters Science. "External Anatomy and Skeletal Structure," Part I of *Dissection of a Fetal Pig.* #15330AC-2, 2 filmstrips with cassettes, Schoolmasters Science.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

carnivore
herbivore
homotherm
mammal
marsupial
monotreme
omnivore
placental mammal
salivary gland
Sus scrofa
vestibule

Review

38. Pigs

Name______________________________

Date_______________________________

Identify the following

______ 1. vestibule

______ 2. salivary gland

______ 3. penis

______ 4. urogenital tubercle

______ 5. elbow

______ 6. papillae

______ 7. canine

______ 8. hoof

______ 9. ears

______ 10. glottis

______ 11. nasopharynx

______ 12. eustachian opening

______ 13. pig

______ 14. frenulum linguae

______ 15. umbilical

A. male

B. part of the forelimb

C. opening to the middle ear

D. opening to the throat and nose

E. third and fourth digits

F. pinnae

G. attaches to the placenta

H. opening to the trachea

I. on the tongue

J. attaches the tongue

K. sublingual

L. between the lips and gums

M. *Sus scrofa*

N. teeth

O. female

Essay

1. Discuss the behavioral, structural, and physiological characteristics common to all mammals.

2. Describe the characteristic differences which separate the monotreme, marsupial, and placental mammals.

39. Laboratory

The Digestive System

When you have completed this laboratory you should be able to:

1. Identify the general internal anatomy of a pig.
2. Identify and trace the organs of digestion from the mouth to the anus.
3. Compare the anatomy of a fetal pig with that of a human.

Digestion

A fundamental characteristic of all organisms is their ability to take in materials and to convert those materials into energy and their own unique protoplasm. A hamburger becomes a boy named Sam, and grass becomes Bill Grogin's goat. This minor miracle is accomplished in mammals by the organs of the digestive tract which reduce and absorb nutrients contained within ingested materials. The undigested or unabsorbed remains of eaten food pass as feces through the anus.

During this laboratory period you will dissect and study the digestive tract of the fetal pig saved from laboratory thirty-eight. The pig has internal structures similar to those of humans. As you carry out this investigation, remember that in both structure and function, the various internal organs of the fetal pig bear a close resemblance to the same parts of your own body.

Pre-lab

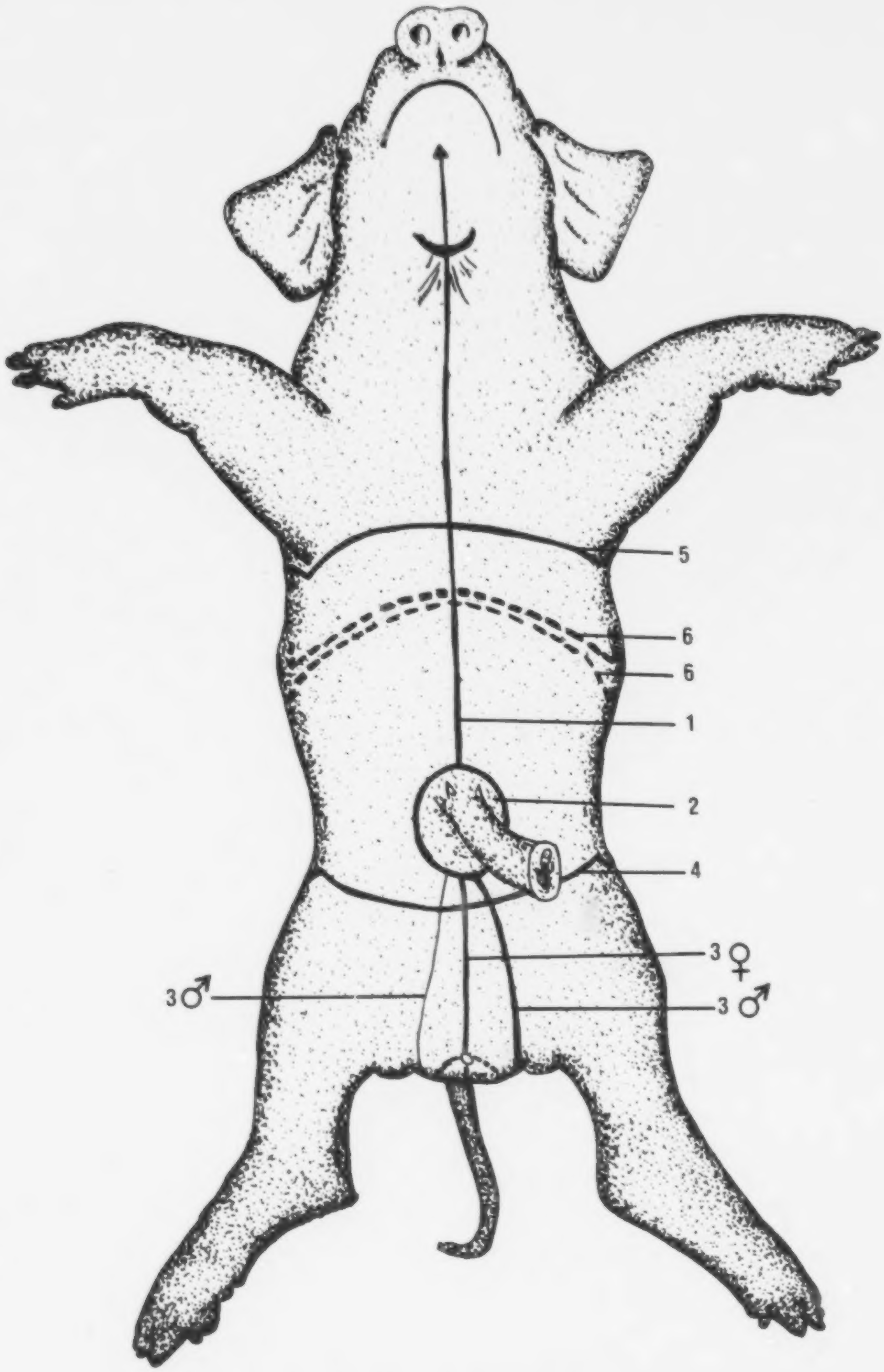
Supplies needed:

Equipment

dissecting pan
scissors
bone shears
forceps
probe
scalpel
dissecting scope or magnifying glass

Materials

preserved fetal pig
plastic bag and tie
string
masking tape



Pig Incisions, in Numerical Order

Figure 1

Special Preparations

The supplies needed for this laboratory are the same as those listed for laboratory thirty-eight. If the student followed directions and labeled and saved the pig, as well as the dissecting equipment, at the conclusion of laboratory thirty-eight, no further preparations are necessary.

Time Required

The digestive system laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Place the pig on its back in the dissecting pan. Spread-eagle its limbs by attaching a string around the lower end of one forelimb and then passing the string under the pan and tying it to the other forelimb. Tie the string so that it is tight and the forelimbs are spread open. Repeat the procedure with the hind legs. As you proceed with the dissection, you may have to tighten the strings.

B. Make incisions through the skin and surface muscle layer in the order and pattern illustrated in figure one. **Do not cut into the body cavities; make only surface layer incisions.**

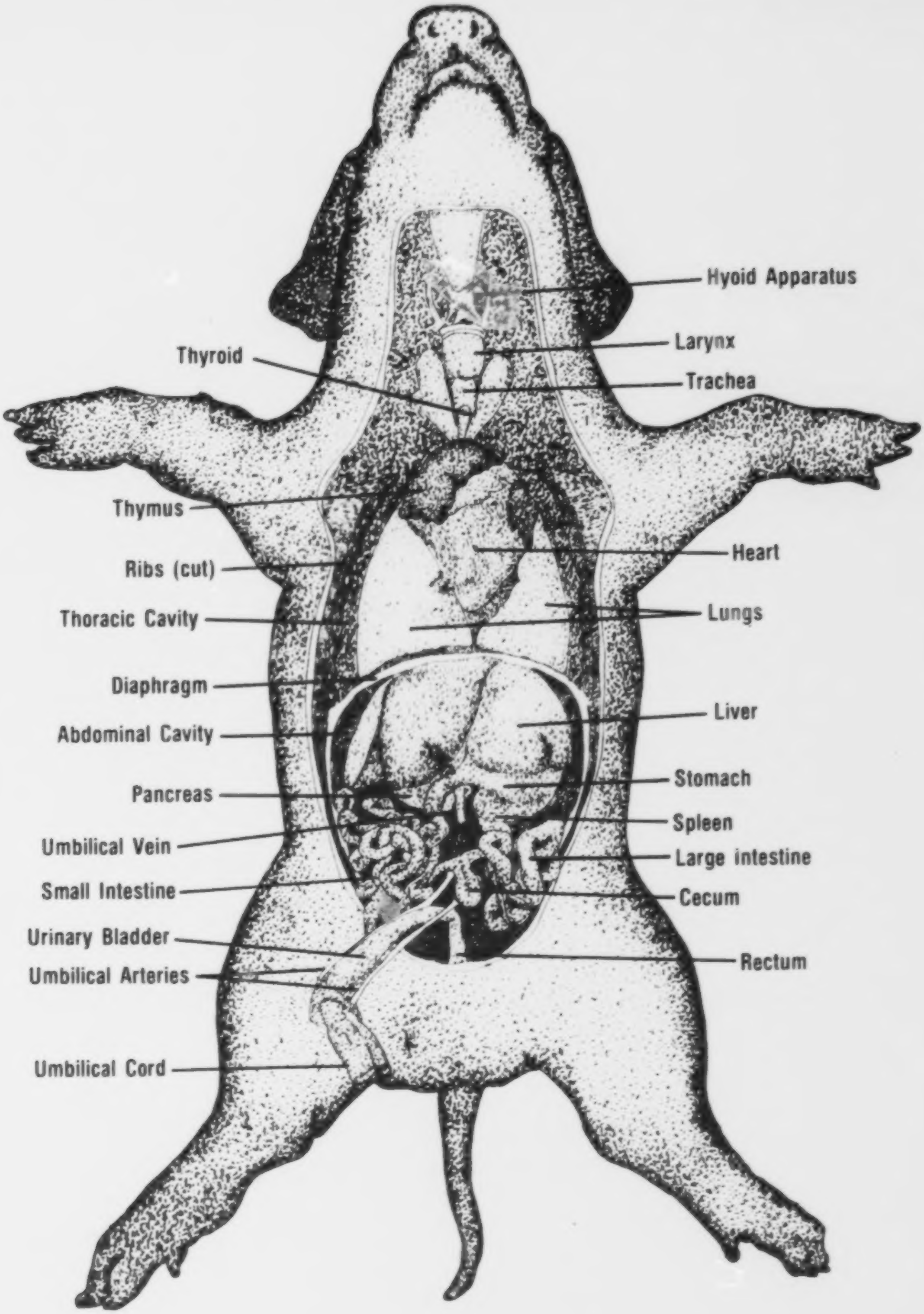
As is illustrated in figure one, if your pig is a female, you may make one cut directly from the umbilical cord to the anus. If your pig is a male, you must make two spread, parallel cuts between the umbilical cord and the anus, to avoid slicing the pig's penis in two.

C. After the incisions have exposed the body cavities, you may notice a dark fluid filling them. Gently flush the cavities with water.

D. Just in front of the hind legs and just caudal to the front legs, cut into and through the body wall in order to make lateral flaps which can be laid back out of the way. Free the diaphragm from the body wall by cutting the edge of the diaphragm where it is in contact with the body wall. This step also is illustrated in the figure one drawing, being represented by double dotted lines.

E. Observe that the umbilical cord and the flesh immediately around it cannot be laid back freely. Look for the umbilical vein. It is a dark, tubular structure extending from the umbilical cord into the liver. Tie a small piece of string around the vein in two places, and then cut through the vein between the two tied-off areas. This procedure keeps any material inside the vein. It also will aid in identifying the umbilical vein later. Now the umbilical cord with its attached strip of flesh can be pulled back.

F. With the aid of the drawing in figure two identify the listed internal structures.


Hyoid Apparatus
Thyroid
Larynx
Trachea
Thymus
Heart
Ribs (cut)
Thoracic Cavity
Lungs
Diaphragm
Liver
Abdominal Cavity
Pancreas
Stomach
Spleen
Umbilical Vein
Large intestine
Small Intestine
Cecum
Urinary Bladder
Rectum
Umbilical Arteries
Umbilical Cord

Pig Internal Anatomy

Figure 2

Viscera, or organs, in the upper body cavity, the thorax:

- Diaphragm: this is a muscular sheet which separates the thoracic cavity containing the heart and lungs from the abdominal cavity which contains the intestines, stomach, and other digestive organs. You had to sever it to expose the pig's body cavities.
- Thymus glands: these are usually large soft structures which extend from the throat down over the top portion of the heart.
- Heart and lungs.

Viscera in the lower body cavity, the abdominal cavity:

- Peritoneum: the smooth shiny membrane lining the abdominal cavity. Part of the peritoneum forms suspensory tissue extending from the dorsal wall of the body in support of the internal organs. This tissue is called mesentery.
- Liver: the large, brownish lobed structure which lies nearest the diaphragm.
- Stomach: it is on the left side of the abdominal cavity and almost entirely covered by the liver.
- Spleen: it is attached to the stomach and is an elongated reddish-brown organ.
- Small intestine: it fills most of the abdominal cavity from the stomach to the anus.
- Large intestine: the spleen partially covers this larger coiled mass of intestines in the left part of the abdominal cavity.
- Urinary bladder: a large sac at the lower end of the pig's body.

G. Have the instructor check your dissection to verify that you have correctly identified your pig's internal organs.

1. Instructor's signature verifying dissection and correct identification of internal organs. ____________________

H. Review the structures of the digestive system which you dissected in laboratory thirty-eight. These included the salivary glands, the mouth cavity, and the pharynx. After you have reacquainted yourself with these structures, continue tracing the digestive system in sequence through the body of the pig, by identifying the following internal structures.

- Esophagus: this is a muscular tube which attaches the pharynx to the stomach through the diaphragm. A muscular, wave-like motion called peristalsis moves food through the entire digestive tract, beginning with the esophagus.
- Stomach: remove the stomach from the abdominal cavity by cutting through the esophagus, and also through the duodenum, where the intestines join the stomach. Notice that where the duodenum joins the stomach there is a stiff ring of muscular tissue. This is the pyloric sphincter which contols the passage of food from the stomach to the duodenum. Study the stomach itself and identify the following stomach areas: the diverticulum, a flattened triangular bulge near the esophagus' entry into the stomach; the lesser curvature, the portion of the stomach between the esophagus' entry and the duodenum's exit; and the greater curvature, which is opposite the lesser curvature.
- Liver.
- Gall bladder: greenish or almost colorless in appearance.
- Pancreas: a long, granular mass lying in the angle between the curve of the stomach and the duodenum.
- Duodenum, jejunum, and ileum: the upper, middle, and lower segments of the small intestine, respectively. The jejunum and ileum superficially look alike. Cut out a small segment of the intestine, open it longitudinally, place it in water, and study the segment under magnification. The velvety appearance of the internal lining is caused by villi, small fingerlike projections of the lining which absorb nutrients from the food passing through the intestinal tract. Most absorption takes place in the duodenum.
- Colon and cecum: the colon is the upper part of the large intestine. The cecum is a pouch formed where the large and small intestines meet. Cut into the cecum where the ileum enters it, wash out its contents, and look for the ileocaecal valve. The colon is responsible for the reabsorption of water from undigested food.
- Rectum: the straight tube extending from the colon to the anus.

2. No food can be found in a fetal pig's stomach. Why not?

3. What are villi?

4. What seems to be the function of the ileocaecal valve?

5. How many lobes does a pig's liver have?

6. In the space provided below, draw your pig's stomach and label the following structures on your drawing: the esophagus, lesser curvature, greater curvature, diverticulum, and duodenum.

I. Reacquaint yourself with the structures and functions of the digestive tract by reviewing earlier dissection laboratories.

7. From earlier discussions and dissections, explain the functions of the liver and gall bladder.

8. What is the function of the pancreas?

J. Place your fetal pig and dissecting pan in a plastic bag with enough water to keep it moist. Tie the bag securely. Label the pan with your name and/or your group name, as well as today's date. Store the bag as well as your dissecting equipment for use in laboratory forty-one.

Resources

Educational Images, Ltd. *Your Body – Series I.* #C 4351, computer disks for Apple II, TRS-80 I and III, and PET. Four quiz programs in a game format.

Prentice-Hall. *Human Physiology: The Gastrointestinal Tract.* #52-3106, 3 filmstrips and cassettes, available from Carolina Biological.

Text-Atlas. "Digestive System," *Tissues and Organs.* Sets 1 and 2, #48-2138 and #48-2140, slides with printed guides available from Carolina Biological.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

diaphragm
duodenum
esophagus
ileocaecal valve
ileum
jejenum
mesentery
peristalsis
peritoneum
pyloric valve
villi

Review

39. The Digestive System

Name____________________________

Date_____________________________

Multiple choice

______ 1. The chief function of the small intestine is
a. absorption of water
b. enzymatic digestion
c. mechanical break-up of food
d. absorption of nutrients and water

______ 2. What is persistalsis?
a. the addition of enzymes to food
b. the process of mechanical digestion
c. the wave-like motion that moves food through the digestive tract
d. two of the above

______ 3. Bile produced by the liver is collected in a storage vessel known as the
a. pancreas
b. appendix
c. colon
d. gall bladder

______ 4. The organ responsible for the absorption of water from undigested food is the
a. small intestine
b. stomach
c. pancreas
d. large intestine

______ 5. Small fingerlike projections found on the inner surface of the small intestine are
a. lymph vessels
b. lacteals
c. cilia
d. villi

______ 6. The tissue which supports the organs of the abdominal cavity is known as
a. mesentery
b. undifferentiated tissue
c. peritoneum
d. the pancreas

______ 7. Material stored in the gall bladder empties into the
a. small intestine
b. large intestine
c. stomach
d. liver

______ 8. The part of the large intestine which leads to the rectum is called the
a. cecum
b. colon
c. duodenum
d. ileum

______ 9. Most nutrient absorption takes place in the
a. stomach
b. upper small intestine
c. lower small intestine
d. large intestine

______ 10. The ileocaecal valve separates the
a. stomach from the esophagus
b. colon from the rectum
c. stomach from the duodenum
d. colon from the small intestine

Place the following digestive organs or structures in the proper sequence, from the mouth to the anus, marking them A through J.

______ 11. colon

______ 12. cecum

______ 13. esophagus

______ 14. ileum

______ 15. stomach

______ 16. duodenum

______ 17. rectum

______ 18. pyloric valve

______ 19. ileocaecal valve

______ 20. jejenum

40. Exercise

Calories and You

When you have completed this exercise you should be able to:

1. Determine whether your diet meets the optimum standards for consumption from the basic food groups.
2. Determine your average daily Calorie intake.
3. Plan a week's diet that meets standards for intake from the basic food groups.
4. Plan a week's diet that meets standards for Calorie intake for your sex, age, and height.

Man's Diet

Man's diet has changed significantly over time. It has been marked by a gradual shift from the diet of prehistoric man, the opportunistic, omnivorous gorger, to that of modern man, the regular nibbler of cereal-based foods. Bodily adjustments to diet changes previously took place over many thousands of years, as human society evolved from hunting/gathering to settled agriculture. However, during the very short time of the past hundred years, with the rapid development of food processing, preservation and storage, long-distance shipping, chemical additives, and a huge sugar industry, man's diet has changed massively. These technologically induced changes have occurred in little more than four generations, and we as yet do not understand how these sudden changes will affect the human body in the longer term.

Understanding dietary trends certainly is necessary for both agricultural and economic reasons. But, more importantly, food has a direct impact on the physical and mental health of a people and their requirements for medical care. Inadequate or improper diet directly impacts the body. Since many modern health problems can be linked to diet, it matters to British nutritionists that their people have greatly increased the consumption of processed potatoes and sugared products in the last twenty years. It also matters to U.S. health personnel that Americans eat a large volume of convenience foods. Analyzing dietary changes and pinpointing practices that place people at risk have become important to medical personnel and government authorities alike.

The HANES Survey

A Health and Nutritional Examination Survey (HANES) was conducted in the United States in 1971 and again in 1974. Data was collected on food ingested over a twenty-four hour period by 28,000 Americans ranging in age from one to seventy-four. Results showed, among other things, that many Americans consume inadequate amounts of iron, calcium, vitamin A, and vitamin C. Still other surveys indicate that a significant proportion of the population maintains inadequate levels of vitamin B^6, folic acid, and certain trace elements. Such nutritional deficiencies in an otherwise well-fed population must be understood and corrected.

Modern Diets

Modern dietary changes are not all negative. For instance, the common practice of iodizing table salt has largely eliminated goiter, and the year-round availability of fruits and vegetables has sharply reduced the incidence of such classic deficiency diseases as scurvy and beriberi. On the other hand, citizens of affluent nations, such as the generally obese Americans, eat too much food which is too high in saturated fats and too low in fiber, minerals, and vitamins. Increased incidence of certain forms of cancer, mature-onset diabetes, and heart attack, for example, have all been clearly linked to bad dietary habits.

Residents of industrialized countries obviously consume many processed foods not available to their ancestors. Processed foods have a much greater Caloric density (energy available per unit weight of food) and a lower nutrient and fiber content than the natural foods they replaced. As a result, processed foods are selectively fortified with iron, thiamine, riboflavin, and niacin, in an attempt to replace nutrients lost during processing. For sales promotion, or nutritional reasons, such factory foods also often are fortified with as many as fifteen different vitamins and minerals. Unfortunately, it is not technically or economically practical to replace all nutrients lost during processing, particularly the trace elements required by some of the body's chemical processes.

Chemical Additives and Imitation Foods

Processed foods also usually contain chemical additives which, while having no food value, have been added to manipulate appearance, texture, taste, and shelf-life. Some previously popular chemical additives have been shown to be carcinogenic, that is cancer-causing, but the long term impact of even apparently benign chemical additives is not always certain.

Imitation foods represent a potentially great dietary problem, partly because people consume something other than what they think they have purchased. For example, increasingly popular imitation milk products usually contain protein and calcium, as expected, but they lack such essential nutrients as riboflavin. It is theoretically possible to obtain a balanced diet by consuming many processed, imitation, and fast foods, if one compensates by carefully selecting at other meals foods that are high in nutrients and fiber. Unfortunately, few of us stop to calculate proper balance or think of our diet in terms other than taste, quantity, and convenience.

This Exercise

It is critical for our long-term health to understand what we eat and how ingested food affects us. In this exercise you will analyze your food intake, both in terms of food group distribution and quantity. From this data you should consider whether what you eat is best for you. Without detailed chemical analysis, it will not be possible to analyze the vitamin and mineral content of your diet. However, you will be able to analyze your diet in terms of distribution between the basic food groups and total Calorie intake.

Food Groups

The basic food groups used in this exercise are milk, protein/meats, fruits, vegetables, and starch/breads. The number of food groups different nutritionists work with vary from as few as four to as many as twelve. For example, diabetic cookbooks have a separate category for fats and oils. However, it will be relatively easy to determine whether or not your diet is balanced in terms of the particular five categories used in this exercise. Sustained food group balance, of course, assures that your diet over time contains proper quantities of vitamins, minerals, fiber, protein, and carbohydrates.

Calories and calories

A calorie is a unit for measuring the amount of heat produced during the burning of a fuel. There are two calorie units, that used by physical scientists (here designated lower case "c") and that used by nutritionists (upper case "C"). One nutritional Calorie is equivalent to one scientific kilocalorie. The scientific calorie is the amount of energy required to heat one gram of water one degree centigrade. The Calorie thus equals one thousand calories, or the amount of energy required to heat one thousand grams of water one degree centigrade. When food is described in terms of Caloric content, it describes the kilocalories of energy that could be released when the food is used as fuel to power the body's processes.

NOTE: **Students require access to both a Calorie chart and a listing of the foods which comprise the major food groups in order to complete this exercise. These are available from many sources. Major pharmaceutical companies, as well as federal and state governments, publish complimentary pamphlets which contain such information.**

Additionally, students should make use of the chart, figure one, which lists Calories in some of the more common fast food items. You may wish to request a Calorie list from other fast food restaurants in your neighborhood, as a supplement to this list.

FAST FOOD

Arby's	
Junior Roast Beef	240
Roast Beef	429
Turkey Sandwich/dressing	337
Super Roast Beef	705
Arthur Treacher's	
Fish, Chips & Coleslaw 3 pcs.	1100
Fish, Chips & Coleslaw 2 pcs.	905
Baskin & Robbin's	
One scoop/sugar cone	
Chocolate Fudge	229
French Vanilla	217
Rocky Road	204
Butter Pecan	195
Chocolate Chip Mint	189
Jamoca	182
Fresh Strawberry	168
Peach	165
Mango Sherbet	132
Banana Daiquiri Ice	129
Burger Chef	
Hamburger	250
Double Hamburger	325
Super Chef	530
Big Chef	535
French Fries	240
Chocolate Shake (8 oz.)	310
Burger King	
Whopper	630
Whopper Junior	285
Double Hamburger	325
Hamburger	252
Cheeseburger	305
Hot Dog	291
Whaler	744
French Fries	220
Chocolate Shake	365
Colonel Sander's	
15 piece Bucket	3300
One Drumstick	220
3 piece Special	660
Dinner (Chicken, mashed potatoes, gravy, coleslaw, roll)	
2 piece Original	595
2 piece Crispy	665
3 piece Original	830
3 piece Crispy	1070
Dairy Queen	
Small Cone	110
Medium Cone	230
Small Dipped Cone	160
Dairy Queen—Continued	
Medium Dipped Cone	310
Large Dipped Cone	450
Small Sundae	190
Medium Sundae	300
Large Sundae	430
Small Malt	400
Large Malt	830
Hot Fudge Brownie Delight	580
Banana Split	580
Parfait	460
Dilly Bar	240
DQ Sandwich	190
Buster Bar	390
Super Brazier	850
Brazier Cheeseburger	310
Big Brazier Deluxe	540
Big Brazier	510
Brazier Dog	270
Super Brazier Dog	500
Brazier Chili Dog	330
Brazier	250
Brazier Barbecue	280
Bosn's Mate Fish Sandwich	340
Chicken Pack	342
French Fries	200
Onion Rings	300
Dunkin' Donuts	
Plain Cake Donut	240
Plain Honey Dipped	260
Plain (white icing)	265
Plain (chocolate icing)	235
Chocolate Cake	240
Chocolate Honey Dipped	250
Yeast-raised Donuts (Jelly, Custard, or Cream fillings add 50 calories)	
Sugared	255
Honey Dipped	275
Glazed Coffee Roll	250
Sugared Bismarck	245
Bismarck/white icing	270
Butternut Donut	220
Hardee's	
Huskie Deluxe	525
Huskie Junior	475
Fish Sandwich	275
Hot Dog	265
French Fries	155
Milk Shake	320
Apple Turnover	290
Howard Johnson's	
Small Vanilla Cone	186
Small Chocolate Cone	195
Howard Johnson's—Continued	
Medium Vanilla Cone	247
Medium Chocolate Cone	281
Small Sherbet	136
Large Vanilla Cone	370
Large Chocolate Cone	390
Pecan Pie (1/8th)	474
Fried Clams (7 oz.)	357
McDonald's	
Egg McMuffin	312
Hotcakes, Sausage, Syrup	507
Hamburger	249
Double Hamburger	350
Cheeseburger	309
Quarter Pounder	414
Quarter Pounder/Cheese	521
Big Mac	557
Filet-O-Fish	408
French Fries	215
Hot Apple Pie	265
Chocolate Shake	317
Vanilla Shake	322
Strawberry Shake	315
Pizza Hut	
Individual Cheese	
Thick Crust	1030
Thin Crust	1003
1/2 of 13-inch Cheese Pizza	
Thick Crust	900
Thin Crust	850
1/2 of 15-inch Cheese Pizza	
Thick Crust	1200
Thin Crust	1150
Red Barn	
Cheese Buster	707
French Fries	103
Shake	358
Salad	189
Apple Pie	217
Taco Bell	
Enchirito	391
Frijole	231
White Castle	
Hamburger	164
Cheeseburger	198
Fish Sandwich	200
French Fries	219
Onion Rings	341
Milk Shake	213
Cinnamon Roll	305
Cherry Roll	334

Figure 1

1. Keep a record of everything you eat and drink for one day, in the figure two chart below. Be sure to record in grams the quantities of each food you eat. For your records, one teaspoon equals five grams, one tablespoon equals fifteen grams, one ounce equals thirty grams, and one cup equals two hundred and forty grams. Of course, the actual weight of different types of food varies, but nutritionists use the above averages as a convenient standard.

YOUR FOOD INTAKE FOR ONE DAY			
Food	**Amount(g.)**	**Calories**	**Food Group**

Total Grams: ________________ **Total Calories:** ________________ **Density:** ________________

Figure 2

2. Add and record the total grams consumed in one day at the bottom of the figure two chart above. Also, using a Calorie chart to determine the Caloric content for each item in your list, enter the Calorie count in the column marked Calories, and add the Calorie column to find the total number of Calories you consumed in one day. Record this also in the figure two chart. Next, determine the ratio of Calories to weight by dividing the total Calories consumed in one day by the weight of the food consumed in one day. This determines the Caloric density of the food you consumed per gram unit of weight.

3. Compare your food density and total Calorie intake with others in your class. ________________

____

____

____

4. Class each item on your list according to its inclusion in a basic food group. If you ate a smaller than usual portion, as listed in a food group guide, enter the fraction of a full portion in the figure two column which is labeled food groups, as well as the food group name. If you had more than a standard portion, note that also with an appropriate number, such as 1-3/4, etc., as well as the food group name.

5. Compare your total number of servings from each of the basic food groups with the recommended number of servings for your sex, age, and height (as taken from your food group guide). Enter this data in figure three.

DISTRIBUTION OF YOUR INTAKE DURING ONE DAY		
Food Group	Recommended Servings	Actual Servings
Milk		
Vegetables		
Fruit		
Starch/Breads		
Protein/Meats		

Figure 3

6. How many servings of yellow fruits and vegetables did you include in figure three? ____________________

7. How many servings of citrus fruit or tomatoes did you include in figure three? ____________________

8. Use the recommended number of servings for each of the basic food groups, as well as your recommended Calorie intake, to plan a menu for yourself for a week. Enter this menu in figure four below.

SAMPLE MENU							
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Breakfast							
Lunch							
Dinner							
Snacks							

Figure 4

9. How many Calories per day are included in your planned menu?

Monday	Friday
Tuesday	Saturday
Wednesday	Sunday
Thursday	

10. Does your menu conform to the ideal number of Calories you should consume per day for your sex, age, and height? Why or why not?

11. Do you have the correct proportion of the basic food groups represented on a daily basis in your menu? Why or why not?

12. Consider the diet you have chosen from the point of view of natural versus processed or imitation foods. What percentage of your diet contains processed or imitation foods?

13. How does food density in your sample menu compare with the ideal?

14. How might changing Caloric content and food density change you?

15. Discuss circumstances, such as allergies, which require the substitution of a processed or imitation food for a natural one.

Resources

Hughes, R. E. "Human Dietary Patterns and Technological Change," *Oxford Biology Readers*. Oxford University Press: London, 1971.

Human Relations Media. *Dangerous Dieting: The Wrong Way to Lose Weight.* #771-00-CSGQ, 3 filmstrips and cassettes.

Human Relations Media. *Nutrition and Exercise.* #3267-00-CSGQ, 2 filmstrips and cassettes.

U.S. Department of Agriculture. *Nutritive Value of American Foods in Common Units, Agricultural Handbook 456.* U.S. Department of Agriculture: Superintendent of Documents, U.S. Printing Office, Washington, DC, 1975.

Wilford, Laura. *Nutritive Value of Convenience Foods.* West Suburban Dietetic Association: P.O. Box 1103, Hines, Illinois 60141, 1976.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

calorie
Calorie
food group

Review

40. Calories and You

Name________________________

Date________________________

Short answer

1. What is a food group? Name the food groups used in this exercise.

2. What is a Calorie? What does it measure?

3. What is food density? How might nutritionists use the concept of food density in meal planning?

4. Beside Caloric intake and food group distribution, what other considerations are important for good nutrition?

5. What is the difference between natural, processed, and imitation foods?

6. In the space provided below, write a balanced menu for one day for a person of your sex, age, and height.

41. Laboratory

Circulatory and Respiratory Systems

When you have completed this laboratory you should be able to:

1. Identify and trace the major arteries and veins of the fetal pig's circulatory system.
2. Identify the structures of a mammalian heart.
3. Identify the organs of respiration in a fetal pig.

Blood Circulation and Respiration

All organisms must be able to supply individual cells with energy and to remove wastes which result from use of that energy. Simple animals, such as marine invertebrates, perform these mechanical tasks by direct diffusion, but more complex animals require other methods. Animals with three tissue layers, such as the mammals, have cells which cannot directly contact the environment. They require a transport system to circulate energy compounds, oxygen, nutrients, and waste products to and from the cells. In all vertebrates such materials are transported in the circulatory system, a pump-driven system of tubes which continuously washes all parts of the body in a blood bath.

Closely linked to the circulatory system is the respiratory system, the structures and organs of respiration which take waste gases from the blood and recharge the blood with oxygen for carriage throughout the body. The digestive system studied in laboratory thirty-nine also is directly linked to the circulatory system, in that food absorption from the little intestine and water absorption from the large intestine is through the walls of capillaries specially designed for their role as collectors of useful products of digestion. Similarly, waste products of metabolism are removed from the body by the kidneys which filter the blood and move wastes to the fluid excretory system.

The vertebrate circulatory system not only transports gases, foods, and waste products, but it also performs other important functions. Blood carries the hormones which help coordinate body activities. It also maintains a constant internal environment involving both pH regulation of body fluids and temperature control. Furthermore, the circulatory system carries special cells which function in clotting and wound healing, as well as protecting the body from invading viruses and bacteria.

This Laboratory

In this laboratory you will study the network of arteries and veins of the fetal pig's circulatory system. You also will study the structure of the heart, the pump of the circulatory system, and observe the structures of the respiratory system and see how they integrate into the circulatory system. You should remember, as you look at these fetal pig structures, that their names and position in the body are identical to your own circulatory and respiratory systems.

Pre-Lab

Supplies needed:

Equipment

dissecting pan
scissors
bone shears
forceps
probe
scalpel
dissecting scope or magnifying glass

Materials

preserved fetal pig
plastic bag and tie
drinking straw
string
masking tape

Special Preparations

The supplies needed for this laboratory are the same as those listed originally in laboratory thirty-eight, with the addition of a drinking straw. If the student followed directions by labeling and saving the pig, as well as the dissection equipment, at the conclusion of laboratories thirty-eight and thirty-nine, no further preparations are necessary.

Time Required

The circulatory and respiratory systems laboratory requires one and a half classroom hours, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

During this laboratory hour you will study the structures of the circulatory system.

Steps

A. Remove your partially dissected pig from its plastic bag and drain off any accumulated liquid. Remove and dispose of the organs of digestion studied in laboratory thirty-nine in order to view better the remaining body systems. Remove the glands located in the throat, the thyroid which is located on top of the larynx (the voice box) and the thymus (review laboratory thirty-nine for location). The thyroid gland is part of the endocrine system, and the thymus gland is part of the immune system, neither of which will be traced during pig dissection.

Also remove muscles of the throat region, as well as the spleen, a dark organ that partly hides the stomach on the left side of the pig. The spleen is an organ of the circulatory system responsible for storage of new and disposal of old red blood cells, as well as the manufacture of cells called lymphocytes which are part of the body's immune system. At this point you should have fully exposed the structures of the circulatory and respiratory systems.

Have the instructor or aide check your dissection to verify that you have successfully completed this step.

1. Instructor or aide's signature verifying completion of step A. ________________________________

B. Remove the pericardial sac which surrounds the heart, and identify the four chambers of the heart as well as the blood vessels attached to it.

- Right and left atria are thin-walled chambers with lobed appendages called the auricles lying on top. These are found on the upper sections of the heart, or toward the head.
- Right and left ventricles are large muscular chambers which constitute the remaining musculature of the heart.
- Cranial and caudal venae cavae: two large, dark blood vessels entering the right atrium.
- Pulmonary trunk: comes out of the right ventricle between the two auricles. It divides into the right and left pulmonary arteries which go to the lungs.
- Aorta: the base of the aorta comes out of the left ventricle and is covered by the trunk of the pulmonary artery. The aorta arches caudally and, at the arch, also gives rise to arteries which service the head and forelegs.
- Ductus arteriosus: in a fetal mammal, there is a short connection between the pulmonary trunk and the aorta called the ductus arteriosus. Since fetal lungs do not breathe air, blood is shunted from the right ventricle into the aorta rather than flowing into the lungs. After the baby is born, the ductus arterosus changes into a functionless solid cord called the arterial ligament. Babies can experience difficulties after birth if the ductus arteriosus continues to function.

2. How can you distinguish between the atria and the ventricles?

3. What portions of the body are supplied by blood from those vessels which branch from the top of the aortic arch?

4. What vessels return blood to the heart?

5. What is the function of the ductus arteriosus?

6. What happens when the ductus arteriosus stops functioning?

7. What is the function of the spleen?

C. Study the figure one drawing on page 390, and identify the arteries and veins shown by locating them in your fetal pig.

8. Describe the number and location of the veins caudal to the heart.

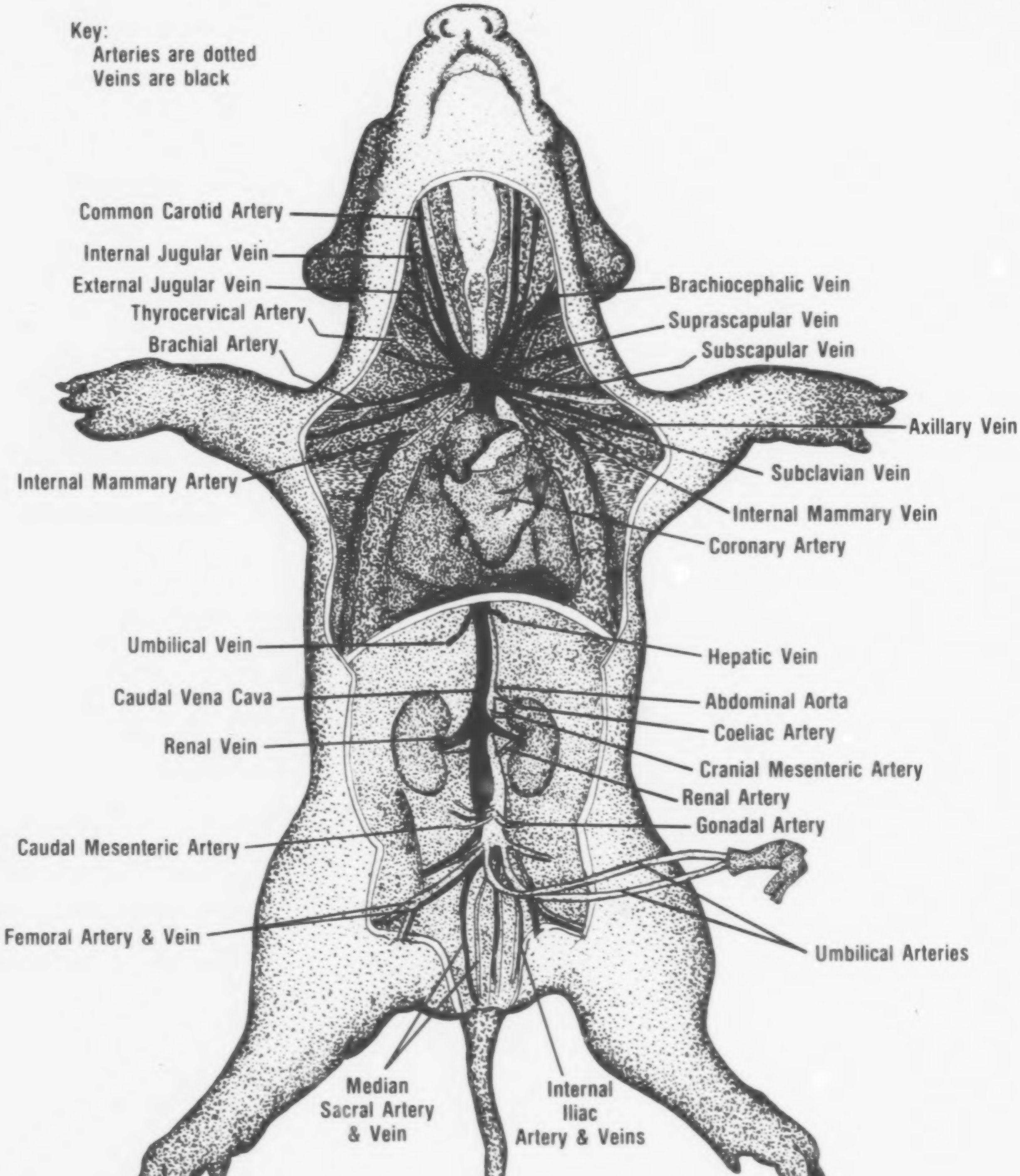
Renals

Iliacs

Median sacral

Umbilical

Hepatic


Key:
Arteries are dotted
Veins are black
Common Carotid Artery
Internal Jugular Vein
External Jugular Vein
Thyrocervical Artery
Brachial Artery
Brachiocephalic Vein
Suprascapular Vein
Subscapular Vein
Axillary Vein
Internal Mammary Artery
Subclavian Vein
Internal Mammary Vein
Coronary Artery
Umbilical Vein
Hepatic Vein
Caudal Vena Cava
Abdominal Aorta
Coeliac Artery
Renal Vein
Cranial Mesenteric Artery
Renal Artery
Gonadal Artery
Caudal Mesenteric Artery
Femoral Artery & Vein
Umbilical Arteries
Median Sacral Artery & Vein
Internal Iliac Artery & Veins

Pig Arteries and Veins

Figure 1

9. Describe the number and location of the veins cranial to the heart.

Vena cava

Jugulars

Subclavians

Mammaries

Hemiazygous (not shown in figure one)

10. Describe the number and location of the arteries caudal to the heart.

Aorta

Coeliac

Mesenterics

Renals

Lumbars (not shown in figure one)

Iliacs

Median sacral

Umbilical

Male pigs also will have paired vessels going from the aorta to the testes through the inguinal canal, along with the ductus deferens. Female pigs have paired vessels running from the aorta to the ovaries.

11. Describe the number and location of the arteries cranial to the heart.

Brachiocephalic

Carotids

Subclavians

Costocervical (not shown in figure one)

Mammaries

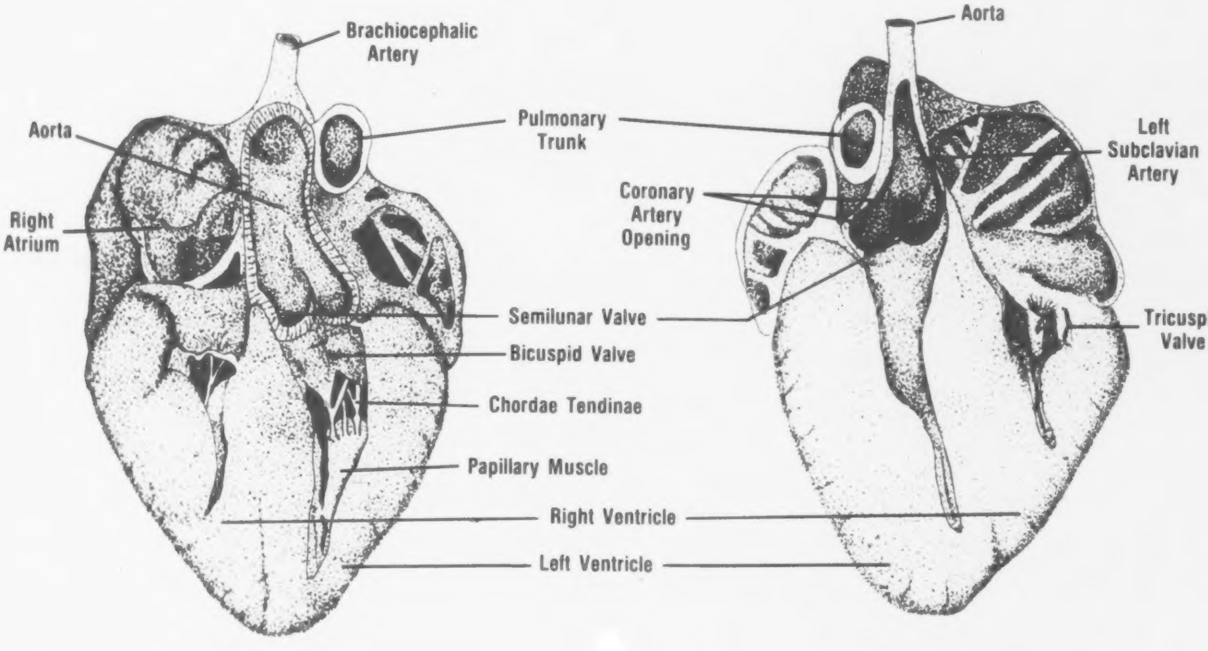
Subscapular

Thyrocervical

D. Remove a fifteen to twenty centimeter section of an artery and a similar section of vein. Slice both sections open lengthwise, gently pick out any latex, and rinse with water. Observe these sections under magnification.

12. Compare the structure of an artery with that of a vein.

E. Cut the heart from your pig's body and slice it in half as shown in figure two below. Gently rinse the heart with water to remove any dark fluid. Study the structures found in the heart, as indicated in figure two, as well as the design of the three valves. Observe these structures under magnification.


Brachiocephalic Artery
Aorta
Right Atrium
Pulmonary Trunk
Coronary Artery Opening
Aorta
Left Subclavian Artery
Semilunar Valve
Bicuspid Valve
Tricuspid Valve
Chordae Tendinae
Papillary Muscle
Right Ventricle
Left Ventricle

Internal Ventral View

Internal Dorsal View

Fetal Pig Heart

Figure 2

13. Describe the structure and location of the following valves. Also note in which direction, from the way they are constructed, they would force blood to flow.

Semilunar ____________________

____

____

Bicuspid ____________________

____

____

Tricuspid ____________________

____

____

F. Place your fetal pig and dissecting pan in a plastic bag with enough water to keep it moist. Tie the bag securely. Label the pan with your name and/or your group name, as well as today's date. Store the bag as well as your dissecting equipment for use during hour two of this laboratory.

Procedure: Partial Hour 2

Students need all listed supplies.

During this partial laboratory hour you will study the organs of respiration.

Steps

A. Remove your partially dissected pig from its plastic bag and drain off any accumulated liquid. Review the location and structure of the following external and mouth structures of the respiratory system which you studied during laboratory thirty-eight: the nostrils, nasal chambers, glottis and epiglottis, and pharynx.

B. Identify the following additional structures.

- Hyoid apparatus: this is not part of the respiratory system, but its location in the body requires that you look at it at this point in your dissection. The hyoid apparatus is a bone located cranially to the larynx, or voice box. It supports the base of the tongue and consists of a ventral body with a pair of horn-shaped structures on either side. The shorter horns, or cornua, lie on either side of the cranial end of the larynx, and the much longer cornua curve dorsally up to end at the base of the tongue.
- Larynx, or voice box: it consists of four cartilages, the largest of which is the thyroid cartilage which you removed in order to study other pig structures at the beginning of this laboratory. The fourth cartilage is the epiglottis, which you observed during laboratory thirty-eight. Free the larynx by cutting between it and the hyoid apparatus, push the thyroid and other cartilages to one side, and identify the soft muscular tube, or esophagus, lying on the other side.
- Trachea: this is supported throughout its length by a series of cartilaginous rings which are incomplete dorsally. It continues from the larynx and divides into two branches called bronchii, which go to the lungs. The bronchii divide into finer and finer branches, or bronchioles, in the lungs, and eventually end as microscopic air spaces called alveoli. It is through the thin walls of the alveoli that the exchange of oxygen and carbon dioxide takes place in mammals.
- Lungs: cut through the trachea midway between the larynx and the lungs, and remove them from the body. The space in the thoracic cavity where the lungs were removed is the pleural cavity, one on either side. These cavities are lined with parietal pleura, or membranes, and the lungs are covered with visceral pleura. The right lung consists of four lobes and the left of three.

14. In the space provided below, draw the hyoid apparatus, the larynx, and the base of the tongue.

15. In the space provided below, draw a ventral view of the larynx, trachea, lungs, and heart as they connect with each other. Be sure to include all the lobes of the lungs, and to label each structure.

16. What is the function of the cartilaginous rings that encircle the trachea and its branches?

17. Study the position of the lungs and the diaphragm of your fetal pig. What is the function of the diaphragm?

18. Do the lungs of your pig completely fill the pleural cavities? Why or why not?

19. Stick a straw in one end of the trachea, and blow through the straw. What happens to the lungs?

20. What causes the lungs to react in question nineteen?

C. Place your fetal pig and dissecting pan in a plastic bag with enough water to keep it moist. Tie the bag securely. Label the pan with your name and/or your group name, as well as today's date. Store the bag as well as your dissecting equipment for use during laboratory forty-three.

Resources

Carolina Biological. *Transport.* #40-1222 for Apple II or #40-1223 for TRS-80, computer program with a question/information format.

Prentice-Hall. *Human Physiology: Circulation.* #52-3102, 3 filmstrips and cassettes, available from Carolina Biological.

Prentice-Hall. *Human Physiology: Respiration.* #52-3104, 2 filmstrips and cassettes, available from Carolina Biological.

Science and Mankind. *Respiration: Energy for Life.* 4 filmstrips, record, and cassettes.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- aorta
- artery
- atrium
- bicuspid valve
- ductus arteriosus
- hyoid apparatus
- larnyx
- pleural cavity
- pulmonary
- semilunar valve
- spleen
- trachea
- tricuspid valve
- vein
- ventricle

Review

41. Circulatory and Respiratory Systems

Name ______________________________

Date ______________________________

Multiple choice

______ 1. Arteries carry blood
- a. toward the heart
- b. away from the heart
- c. to the vena cavae
- d. to the left ventricle

______ 2. The thymus is part of the ____________ system.
- a. endocrine
- b. immune
- c. digestive
- d. nervous

______ 3. The pulmonary arteries carry blood from the heart to the
- a. lungs
- b. liver
- c. kidneys
- d. intestines

______ 4. The largest veins, the vena cavae, lead into the
- a. right atrium
- b. left atrium
- c. liver
- d. left ventricle

______ 5. The hyoid apparatus is located in the
- a. heart
- b. throat
- c. liver
- d. pleural cavity

______ 6. The larynx is also known as the
- a. voice box
- b. throat
- c. stomach
- d. tongue

______ 7. This vessel functions only in the fetus.
- a. vena cava
- b. arteriole
- c. aortic arch
- d. ductus arteriosus

______ 8. This vessel is a cartilaginous tube leading to the lungs.
- a. esophagus
- b. trachea
- c. artery
- d. ductus arteriosus

______ 9. Blood cells are destroyed in this organ.
- a. spleen
- b. larynx
- c. kidney
- d. epiglottis

______ 10. The heart lies in the ________________ cavity.
- a. pleural
- b. pericardial
- c. abdominal
- d. tracheal

Identify structures of the fetal heart by placing letters given in figure three next to the appropriate numbered terms.

______ 11. pulmonary trunk

______ 12. brachiocephalic artery

______ 13. left ventricle

______ 14. right ventricle

______ 15. aorta

______ 16. right atrium

______ 17. semilunar valve

______ 18. chordae tendinae

______ 19. bicuspid valve

______ 20. left atrium

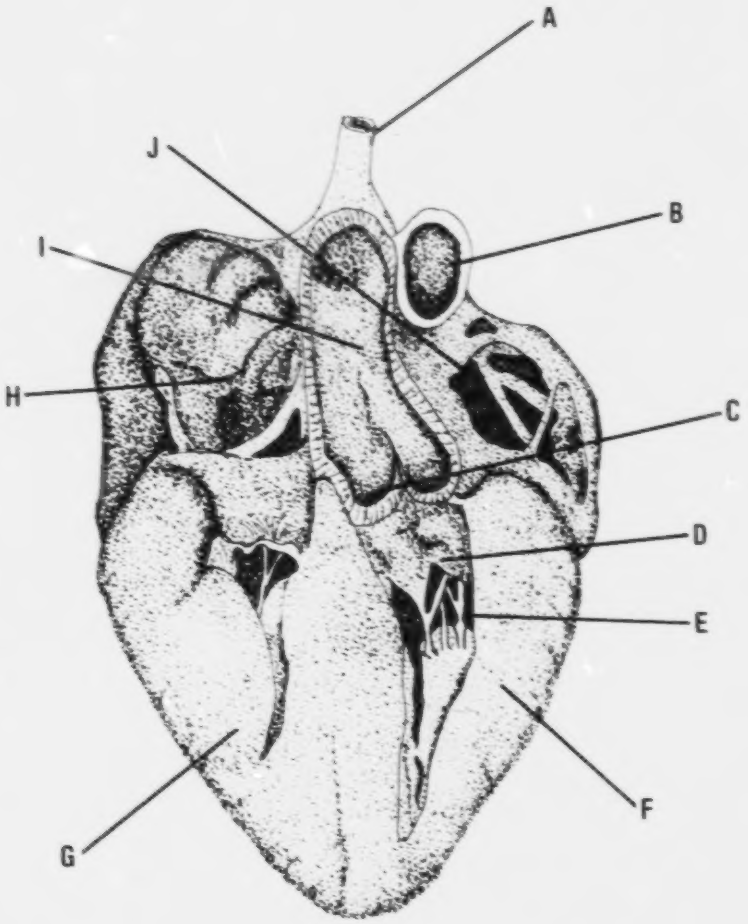


Figure 3

42. Exercise

Your Pulse Rate

When you have completed this exercise you should be able to:

1. Locate your pulse.
2. Determine your pulse rate at rest, during vigorous exercise, and after vigorous exercise.
3. Understand how pulse rate is influenced by activity.
4. Determine your cardiovascular fitness, as compared with your classmates.

Heartbeat and Breathing Rates

Your heart steadily pumps blood to and from all cells in your body. The rate of heartbeat speeds up or slows down in response to the body's requirements for energy, oxygen, or waste removal. The result is the circulation of more or less blood through the body during a given period of time. Respiration, which removes carbon dioxide and adds oxygen to the blood, also varies according to the body's level of activity and cellular requirements.

The autonomic nervous system largely controls these rates. Nerve impulses constantly go from the nervous system to the heart and lungs instructing them to maintain or vary their current rates. Major factors controlling the signals and the resulting rates are activity level and physical condition, but respiration and heartbeat rates also are influenced by such factors as sex, age, lung gas pressure, blood pressure, and the temperature of both the environment and the body.

Exercise, Respiration, and Pulse Rate

Muscular activity associated with exercise rapidly consumes oxygen and produces carbon dioxide (as well as other wastes). Thus, during exercise, the body requires more oxygen and must also eliminate more carbon dioxide than when it is at rest, thereby leading to an increase in heartbeat and breathing rates. During heavy exercise, the volume of air reaching the alveoli may increase up to twenty times the resting volume. The autonomic nervous system stimulates increased respiration and blood pumping at the same time muscles increase their activity. How this linked stimulation occurs is not fully understood, but it is known that changes in blood carbonate and pH levels also occur during exercise.

Blood leaving the lungs through the pulmonary veins, either while the body is at rest or during exercise, is about 97% saturated with oxygen. The factor that seems most to limit oxygen delivery to the tissues is not lung ventilation capacity, which can be increased with comparative ease, but the volume of blood the heart can pump. The heart, through physical training, can be strengthened, and its ability to move larger volumes of blood with each beat can be increased. The heart which is not so strengthened has to increase its pumping rate, the pulse rate, in order to increase the circulation of oxygenated blood required by the tissues during heightened activity levels.

Pulse Rate Tests

Everyone has a pulse rate which varies widely during a full day, depending upon activity, physical and emotional condition, age, etc. During this exercise you will determine your own pulse rate while at rest, during vigorous exercise, and after vigorous exercise. You also will estimate your cardiovascular fitness by determining how long it takes your pulse to return to normal after ending physical exercise and then comparing your results with others in the class.

NOTE: **You will need a stopwatch or clock with a second hand in order to complete this exercise. You need to come to school the day of this exercise dressed in comfortable, casual clothing, or, your instructor may assign the personal testing portions of the exercise as homework.**

Locate your pulse by placing your index and middle fingers on the inside, thumb side of your left wrist. Press lightly. You should feel your pulse. You can also locate your pulse by placing your index and middle fingers over either of the carotid arteries in your neck. **Do not use your thumb to take your pulse rate as it also has a weak pulse.** If you cannot find your pulse, ask your instructor for help.

1. Find a comfortable sitting position, relax for one minute, and take your pulse for thirty seconds. Count three separate times the number of pulses during a timed thirty second period. Do not worry if your pulse varies slightly during these tests. Record the three results in the chart, figure one below. Next, determine and record the pulse rates per minute.

YOUR PULSE RATE			
Condition	**Trial**	**Beats/30 Seconds**	**Rate/Minute**
Rest	#1		
	#2		
	#3		
Exercise	#1		
	#2		
	#3		
After Exercise	#1		
	#2		
	#3		
	#4		

Figure 1

2. Run in place, lifting your knees parallel to your waist as you do so, for exactly five minutes. Push your body as hard as you can so that the results accurately indicate your physical condition. Stop. Count your pulse for thirty seconds, and record the information in the figure one chart above. Repeat this procedure twice more, recording after each timed period your pulse rate immediately after vigorous physical exercise. When you have recorded the count after the third test, calculate your pulse rates per minute.

3. Run in place five more minutes, for a total running time of twenty minutes, and record your pulse count for thirty seconds in the After Exercise Trial #1 column of the figure one chart above. Sit quietly for exactly five minutes. After five minutes rest, take and record your pulse rate as Trial #2. Take your pulse rate every five minutes until your pulse has returned to the rate it held during your initial resting trials. (Some students will need to add fifth and sixth trials to the four provided in the figure one chart above, while others will not need to enter information in all four cells because their pulse will return to normal more quickly). Also determine the rates per minute.

4. Compare your results with other classmates. This can be done by putting the figure one chart on the blackboard and drawing the chart large enough to hold data from the entire class. Alternatively, students can verbally give their individual results during class time. Record these results in the figure two chart below.

CLASS PULSE RATES PER MINUTE										
Student Name	Resting Trial			Exercise Trial			After Exercise			
	#1	#2	#3	#1	#2	#3	#1	#2	#3	#4

Figure 2

5. Record the class averages, as well as the averages for each trial by sex, in the figure three chart below.

AVERAGE PULSE RATES PER MINUTE										
Category Averages	Resting Trial			Exercise Trial			After Exercise			
	#1	#2	#3	#1	#2	#3	#1	#2	#3	#4
Males										
Females										
Class										

Figure 3

6. After exercise, who returned to a normal pulse rate faster, males or females? Why?

7. Does the average data for your sex show that you return to normal faster or slower than the class average? Why?

8. How would you rate your cardiovascular fitness? Why?

9. What factors other than exercise might increase your heatbeat rate?

10. Sit near a sink or pan full of water. Have a classmate, friend, or family member time you. Put your entire face under water for exactly one minute. Immediately take your pulse count for thirty seconds. Repeat this exercise for two more times, and record your pulse count per minute in the figure four chart below.

YOUR PULSE RATE PER MINUTE UNDER VARYING CONDITIONS							
Water Trial				Breath Holding Trial			
#1	#2	#3	Average	#1	#2	#3	Average

Figure 4

11. Hold your breath for exactly one minute. Immediately take your pulse count for thirty seconds. Repeat this exercise two more times, and record your pulse count per minute in the figure four chart.

12. Compare your pulse rates at rest (figure 1), with your face under water, and also while holding your breath. What might account for the differences or similarities in the rates you have recorded?

Resources

Human Relations Media. *Homeostasis: Maintaining the Body's Internal Environment.* #779-00-CSGQ, 2 filmstrips and cassettes.

Sunburst. *The Physiology of Exercise.* #52-3115, 2 filmstrips and cassettes, available from Carolina Biological.

Review

42. Your Pulse Rate

Name______________________________

Date______________________________

Essay

1. How are oxygen and metabolic waste products transported to and from the cells of the body? Explain how the circulatory and respiratory systems function in this process.

2. During exercise, certain changes occur within the body of the active animal. Explain in what ways these changes affect the activity of the heart.

3. Explain what your individual pulse rate tests, when compared with the whole class, tell you about your physical condition. What do these results tell you about the long-term benefits of regular exercise?

43. Laboratory

Excretory and Reproductive Systems

When you have completed this laboratory you should be able to:

1. Identify the organs of excretion in a pig.
2. Identify the structures of a mammalian kidney.
3. Identify the organs of reproduction in both a male and female pig.

Excretory and Reproductive Systems

The excretory and reproductive systems of mammals are usually studied together, particularly when performing dissections, because of their location near each other, and also because of their shared body openings. However, this is strictly a matter of convenience and is unrelated to the separate functions of the two systems. Some texts group the two systems together as the urogenital system, but this confuses the fact that the two systems function very differently.

The excretory system, of course, voids liquid wastes removed from the bloodstream. Some minor excretion also occurs through the skin in sweat, and also through the digestive tract, where intestinal waste products are removed along with undigested food, but the bulk of mammalian excretion results from the kidneys' filtering of wastes from the bloodstream, storage of urine in the bladder, and periodic excretion through the urethral tubes.

A reproductive system is required for the perpetuation of the species. In mammals, it consists not only of ovaries and testes, and the structures for fertilization, but also of a female uterine structure capable of protecting and nurturing the young until parturition, or birth, and mammary glands for feeding the young after birth.

In this laboratory you will study the excretory and reproductive systems of the fetal pig. You also will study the structure of the kidneys and how the structures of the excretory and reproductive systems are integrated into the body. You should remember, as you look at these fetal pig structures, that their names and positions in the body are nearly identical to your own.

Pre-lab

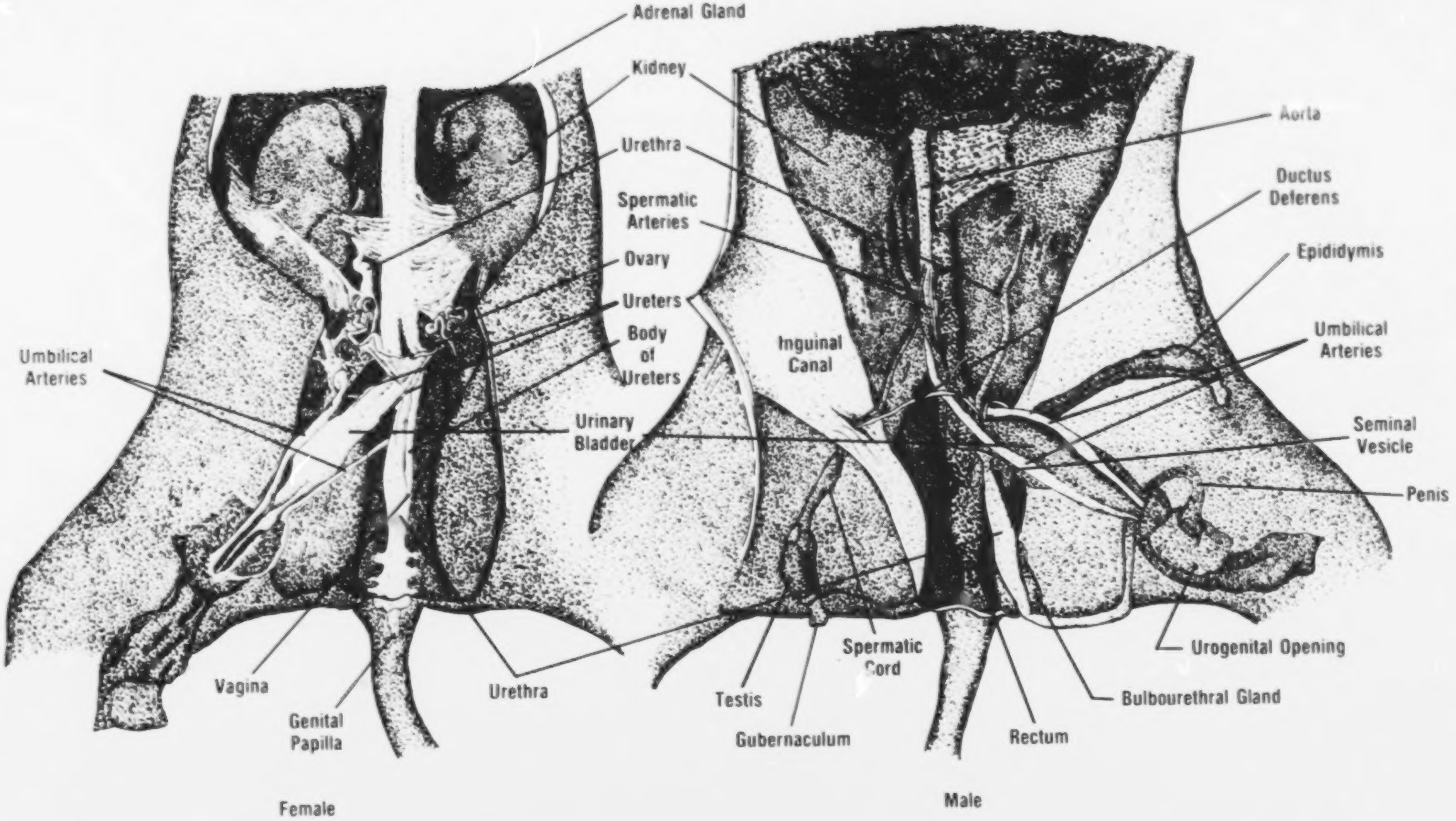
Supplies needed:

Equipment

dissecting pan
scissors
bone shears
forceps
probe
scalpel
dissecting scope or magnifying glass

Materials

preserved fetal pig
plastic bag and tie
drinking straw
string
masking tape


Adrenal Gland
Kidney
Urethra
Spermatic Arteries
Ovary
Ureters
Body of Ureters
Urinary Bladder
Umbilical Arteries
Vagina
Genital Papilla
Urethra
Female
Aorta
Ductus Deferens
Epididymis
Umbilical Arteries
Inguinal Canal
Seminal Vesicle
Penis
Urogenital Opening
Bulbourethral Gland
Rectum
Spermatic Cord
Testis
Gubernaculum
Male

Pig Reproductive and Excretory Systems
Figure 1

BEST COPY AVAILABLE

Special Preparations

The supplies needed for this laboratory are the same as those listed originally in laboratory thirty-eight, with the addition of a drinking straw. If the student followed directions by labeling and saving the pig, as well as the dissecting equipment, at the conclusion of laboratories thirty-eight, thirty-nine, and forty-one, no further preparations are necessary.

Time Required

The excretory and reproductive systems laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Remove your partially dissected pig from its plastic bag and drain off any accumulated liquid. Study the pair of kidneys, dark, bean-shaped organs, lying on the dorsal body wall of the pig, behind the peritoneum, the smooth, shiny membrane lining the abdominal cavity. Use your dissecting needle to pick off the peritoneum, as well as any fatty deposits in the area. Spread-eagle the hind legs as far apart as possible, and cut through the cartilage and muscles of the pelvic girdle so that the legs lay out flat.

B. Identify the structures you observe in this area of the pig's body, using the figure one drawing to help you in your observations.

Have the instructor or aide check your dissection to verify that you have successfully completed steps A and B.

1. Instructor or aide's signature verifying completion of steps. ______________________________

C. Locate the ureter, a tubular structure which emerges from the medial face of the kidney. The renal artery and vein, identified in laboratory forty-one, also enter the kidney near the ureter. The ureter carries urine to the bladder, which is an elongated sac lying between the umbilical arteries. The bladder continues into the umbilical cord where it is known as the allantoic duct. When a mammalian fetus is born, this duct closes.

Remove one of the kidneys and a portion of its urethra from the body. Slice it sagittally, that is, cut it lengthways through the middle of the organ. Observe a section of the kidney under magnification. Identify the following internal and external structures.

- Ureter: the medial face of the kidney where the ureter and renal vessels enter is called the hilum.
- Renal artery and vein.
- Adrenal gland: this sits like a cap on the cranial end of the kidney. It is part of the endocrine system. Hormones secreted by this gland flow directly into the bloodstream to help control many body functions, such as heartbeat, the regulation of blood sugar levels, dilation of muscles in the respiratory system, and the development of certain secondary sexual characteristics.
- Pelvis: the expanded portion of the ureter within the kidney.
- Capsule: the outer covering of the kidney.
- Cortex: the meaty area surrounding the central part of the kidney. The cortex produces steroids such as sex hormones and hormones involved in regulation of metabolic functions. This also is the section of the kidney where blood filtration occurs.
- Medulla: the central area of the kidney. It contains smaller subdivisions of the renal pelvis called calyces; the many blood vessels and protuberances of tissue at the ends of the calyces are called papillae. Study these under magnification. Urine is collected from the cortex in the pelvis of the medulla for transfer to the bladder.

2. In the space provided below, draw a sagittal section of the kidney, labeling it with the structures listed in step C.

3. How do the kidneys help maintain homeostasis in terms of chemical and fluid balance in mammals?

4. Insert a straw into the bladder of your pig, and blow air into it. What happens? What happens if you continue to exert slow but steady air pressure on the bladder? Why does this happen?

D. For this step, student groups who are dissecting a female fetal pig need to coordinate their work with a student group which is dissecting a male fetal pig, and vice versa. Every student group should study both male and female reproductive structures and compare the anatomy of the two sexes. Identify the following reproductive structures.

Female Reproductive System

- Ovaries: small bean-shaped bodies lying on the dorsal body wall near the caudal end of the kidneys. Each ovary is held by a sheet of connective tissue called the broad ligament, as well as attached to the caudal wall of the pelvis by a smaller round ligament.
- Tubes, horns, and the uterus: the small coiled tubes emerging from the dorsal face of each ovary are known as oviducts or fallopian tubes. The horns, or cornua, are larger, convoluted continuations of the tubes attached to the free ends of the broad ligament. The two horns eventually unite into a common structure, the body of the uterus, or womb. Because the uterus is formed from the two horns, it is called a bicornuate uterus. This differs from the human uterus, in that fetal pigs develop in the horns and not in the body of the uterus itself. Many animals have this type of uterus, those that can produce large litters.
- Vagina: near the base of the uterus there is a slight constriction which marks the cervix, or mouth of the womb. Posterior to the cervix is the vagina. It is a muscular tube continuing from the body of the uterus and opening to the outside.

- Urogenital sinus: a common area into which both the urethra and vagina open.
- Vulva: the external genitalia. This includes the labia, or lips, on either side of the urogenital opening, and the clitoris, a small rounded body of erectile tissue on the ventral floor of the urogenital sinus.

Male Reproductive System

- Scrotal sac and contents: slit the scrotum in the middle and pull out the two dark colored sacs inside. Remove one of these sacs and cut it open to expose a testis. The sperm duct, consisting of the ductus deferens, the spermatic artery and vein, and spermatic nerve, proceeds from the testis into the abdomen of the animal. The epididymis is a tightly coiled mass of tubules which lies on one side of a testis and which connects the tubules of the testis to the sperm duct. A gubernaculum, or tough white cord, connects the caudal end of the testis to the inner face of the sac. The gubernaculum is analogous to the round ligament in the female pig.
- Inguinal canal: an opening surrounded by a ring of muscle which connects the abdominal cavity and the scrotal sac. The sperm duct passes through this canal.
- Penis: cut through the muscles in the midventral line between the hindlegs. Remove muscle and pubic bone on each side of the cut until the urethra is exposed. Free the urethra from the rectum by cutting through any muscles or connective tissue you find. The penis is a white tubular structure immediately underneath the urinary bladder. On either side of the junction between the urethra and the penis are the bulbourethral glands. The prostate is a small gland located between the bases of the seminal vesicles. The prostate produces an alkaline, thick, fluid which is the primary component of semen. The seminal vesicles are small sperm storage glands on the dorsal surface of the urethra at the point where the ductus deferens enters.

5. In the space provided below, draw the reproductive organs of a female pig as they connect with one another. Label all structures listed in step D.

6. In the space provided below, draw the reproductive organs of a male pig as they connect with one another. Label all structures listed in step D.

7. What structural similarities exist between the male and female reproductive systems?

8. What structural differences exist between the male and female reproductive systems?

9. The uterus of a pig is a bicornuate uterus, unlike the human uterus. What is the adaptive advantage to the pig in having a bicornuate uterus? What disadvantages might there be?

10. Why might some people refer to the excretory and reproductive systems as a single system? ____________

____

____

____

____

E. Place your fetal pig and dissecting pan in a plastic bag with enough water to keep it moist. Tie the bag securely. Label the pan with your name and/or your group name, as well as today's date. Store the bag as well as your dissecting equipment for use in laboratory forty-five.

Resources

Carolina Biological. *Excretion.* #40-1262 Apple II or #40-1263 TRS-80, computer disks with a question/information format.

Human Relations Media. *Homeostasis: Maintaining the Body's Internal Environment.* #779-00-CSGQ, 2 filmstrips and cassettes.

Prentice-Hall. *Male and Female Reproductive Systems.* #52-3108, 4 filmstrips and cassettes, available from Carolina Biological.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

adrenal gland
gubernaculum
inguinal canal
penis
prostate
scrotal sac
ureter
urinary bladder
urogential sinus
uterine tube
uterus
vagina
vulva

Review

43. Excretory and Reproductive Systems

Name____________________________

Date_____________________________

List in order, beginning with the testis, male reproductive structures.

______ 1.

______ 2.

______ 3.

______ 4.

______ 5.

______ 6.

A. penis

B. inguinal canal

C. ductus deferens

D. epididymis

E. urethra

F. seminal vesicle

List in order, beginning with the ovaries, female reproductive structures.

______ 7.

______ 8.

______ 9.

______ 10.

______ 11.

A. vulva

B. bicornuate uterus

C. fallopian tubes

D. urogenital sinus

E. vagina

List in order, beginning with the kidneys, structures of the excretory system.

______ 12.

______ 13.

______ 14.

______ 15.

A. urinary bladder

B. penis/urogenital sinus

C. ureter

D. urethra

44. Laboratory

Urinalysis

When you have completed this laboratory you should be able to:

1. Understand the roles of the kidneys and urine excretion in cleaning the blood.
2. Determine the physical properties of urine.
3. Test pathological urine for the presence of albumin, acetone, and sugar.

The Kidneys and Urine

The kidneys are the major secretory organs of the body. They separate metabolic by-products and excess water from blood plasma and transfer this waste as urine to the bladder for periodic excretion (see laboratory forty-three). This blood filtering maintains proper fluid volume and blood chemistry in the body. As a result, both the volume and composition of urine can vary tremendously, depending upon what needs to be removed from the blood at any given moment. Because of the wide variability of urine, both qualitatively and quantitatively, its analysis can provide great insight into the health and well-being of its maker. Malfunctions within the body often produce chemicals which the kidneys filter into the urine, and urine testing has become a routine medical practice.

The kidneys maintain homeostasis in the body, for example, by excreting excess acids or bases. As a result, the pH of urine varies as a function of the body's need to remove these materials from the blood. For an individual on a typical American diet, urine pH is around 6, indicating a net metabolic acidification, as compared to the normal pH of blood plasma. This is consistent with our knowledge that the typical diet results in a net production of acid. The pH of urine can range from a lower limit of 4.4 up to 8.0.

A typical daily urine volume is about two liters. Most of the fluid filtered by the kidneys each day, approximately one-hundred liters, is reabsorbed, with waste products concentrated in the urine. The urine contains excess hydrogen, sodium, potassium, chlorine, and bicarbonate ions, as well as urea, creatinine, uric acid, and glucose. These compounds give urine its typical yellowish color. Ammonia, the smell of which can develop in baby's diapers, is produced as a by-product from the breakdown of creatinine. Normal urine has a predictable chemical mix, with unusual concentrations indicating a failure within the body.

In this laboratory you will determine the physical properties of your urine. You also will run three standard tests on your urine sample, testing for albumin, acetone, and glucose, and then testing pathologic urine to see the distinction between normal and abnormal urine test results.

Pre-lab

Supplies needed:

Equipment

glass cylinder
6 test tubes
beaker
hydrometer
bunsen burner
ring stand
test tube rack
10 ml. graduated cylinder

Materials

urine sample
28% ammonium hydroxide
concentrated nitric acid
10% glucose solution
Benedict's solution
pH paper and chart
sodium nitroprusside solution
albumin
glacial acetic acid

Special Preparations

1) Urine sample: one member of each laboratory group needs to provide a sample of urine. If the urine cannot be collected on the same day as the laboratory, it should be refrigerated until tested.

2) Many students are interested in what the following tests indicate about their own bodies. This laboratory works just as well if students are allowed to individually test their own urine samples. If this is done, the instructor will need to increase the supplies needed for this laboratory, listed above by laboratory group, to encompass every student in the class. In this case, **every** student should be willing to bring a urine sample for analysis.

3) Sodium nitroprusside solution: place 100 ml. distilled water in a container. Add sodium nitroferricyanide until no more dissolves while stirring. Store in a brown bottle.

4) Benedict's solution:

a) Place 300 ml. distilled water in a 500 ml. pyrex beaker and heat to about 70°C. Add 100 g. crystalline sodium carbonate, $Na_2CO_3 \cdot H_2O$, 100 g. sodium citrate, and 63 g. potassium thiocyanate. Stir until dissolved. Filter.

b) Dissolve 9 g. crystallized copper sulfate, $CuSO_4 \cdot 5H_2O$, in 100 ml. distilled water. Add this solution to the first solution while stirring slowly

c) Add 2.5 ml. of 5% potassium ferrocyanide solution to the other solutions. Mix. Allow to cool. Add distilled water to the 500 ml. mark on the beaker, and store the solution in brown bottles.

5) It is more convenient if the chemical solutions to be used in the laboratory are supplied in individual dropper bottles.

Time Required

The urinalysis laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. To determine the physical properties of your urine, partially fill a glass cylinder with your sample. Study the urine.

Freshly voided urine should be clear. If the urine is not clear, but turbid, this may indicate the presence of protein, pus, or other materials. Also, normal, fresh urine has a faintly aromatic odor. Many drugs and vegetables influence urine odor. For example, diabetic urine, owing to the presence of acetone, has a fruity odor.

1. Describe the smell of your urine (other than the fact that it has an odor). ______________________

____

2. Describe the color and clarity of your urine. ______________________

____

____

B. Test your urine with pH indicator paper. Also determine with a hydrometer the specific gravity of your urine sample.

Remember that the specific gravity of a liquid is its relative weight as compared with that of water. One milliliter of water weighs 1 gram; therefore, the specific gravity of water is expressed as 1.0. The specific gravity of normal urine ranges from 1.010 to 1.025, with the higher number indicating more dissolved solids.

3. What is the pH of your urine? How does this compare with the figures given for normal urine in this laboratory?

____

____

____

4. What is the specific gravity of your urine? How does this compare with the figures given for normal urine?

____

____

____

C. Pour 5 ml. each of your urine sample into three test tubes. Label one test tube "Heller," one "Lange," and one "sugar," and place these test tubes in a test tube rack. Prepare pathologic urine by adding a pinch of albumin, 10 drops acetone, and 15 drops 10% glucose solution to the rest of your urine. Pour 5 ml. each of this pathologic urine into three more test tubes and label one "Heller pathologic," one "Lange pathologic," and one "sugar pathologic," and place these test tubes in the test tube rack. You should now have six labeled test tubes ready for testing.

D. The Heller ring test for albumin: slant a test tube labeled "Heller" and **carefully** pour 2 to 3 ml. concentrated nitric acid down the side so that it flows gently onto the top of the urine sample. Gently right the test tube and observe it. Two distinct layers should form. Repeat the procedure for the second "Heller" test tube.

The formation of a white ring at the junction of the urine and the nitric acid indicates the presence of albumin, a protein.

Albumin is one of the three primary blood plasma fractions. Under normal circumstances, it should not pass into the urine. If it does, it indicates that the permeability of the kidneys' capillaries has abnormally changed. When albumin is detected in the urine, it is called albuminuria. Aside from disease, albumin in the urine may be caused by very heavy exercise, blood from the bladder, or vaginal discharges, in which cases the test result is called false albuminuria.

5. Was the test for albumin positive for the "Heller pathologic" urine? Why or why not? ______________

____

____

6. Was the test for albumin positive for the "Heller" urine? Why or why not? ______________

____

____

If the test for albumin in your normal urine was positive, you may wish to retest for albumin using a fresh urine sample.

E. Lange's test for acetone: add 5 drops glacial acetic acid and 3 drops saturated sodium nitroprusside solution to each of the test tubes labeled "Lange." Mix. Slowly add about 20 drops of 28% ammonium hydroxide, slanting each test tube carefully as you do so. Gently right the test tubes and observe them.

A purple or purplish-red ring at the junction of the urine mixture and the ammonium hydroxide indicates the presence of acetone.

Acetone is a ketone excreted by the body when the body oxidizes fat instead of glucose. If the body cannot properly oxidize glucose to supply its energy needs, it catabolizes fat. Diacetic acid is produced during fat catabolism. The diacetic acid breaks down, liberating acetone and beta-oxybutyric acid. The acetone is then excreted from the body. The presence in urine of such ketones as acetone is one sign of diabetes.

7. Was the test for acetone positive for the "Lange pathologic" urine? Why or why not?

8. Was the test for acetone positive for the "Lange" urine? Why or why not?

9. What other physiological conditions besides diabetes might produce acetone in the urine?

If the test for acetone in your normal urine was positive, you may wish to retest using a fresh urine sample.

F. Sugar in the urine: add a dropperful of Benedict's solution to the two test tubes labeled "sugar." Set up a boiling water bath with the bunsen burner, ring stand, beaker, and water. Place the two test tubes in the boiling water bath for five minutes. Observe them for any color changes.

Glucose reduces copper, which is present in Benedict's solution, to cuprous oxide. Cuprous oxide is easily detectable as a greenish to yellowish to orangish-red precipitate. The actual color depends on the concentration of sugar found in solution (review laboratory five). A color change indicates the presence of sugar in the urine.

Glucose in urine is called glycosuria. It is one sign of diabetes, but glucose in the urine may also be found after strenuous exercise or emotional upset. If a lot of sugar is found, it means that the renal threshold, or the ability of the kidneys to handle the substance, has been reached and exceeded. Renal thresholds vary between individuals, so a positive glucose test is usually combined with blood and other tests to confirm pathology. A sufficiently high glucose level and its associated blood electrolyte imbalance can lead to shock and death.

10. Was the test for sugar positive for the "sugar pathologic" urine? Why or why not?

11. Was the test for sugar positive for the "sugar" urine? Why or why not?

12. What other physiological conditions besides diabetes might result in the presence of sugar in the urine?

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If the test for sugar in your normal urine was positive, you may wish to retest for it using a fresh urine sample.

If any of the urine retests for albumin, acetone, or sugar continue to be positive, you should consult your doctor.

Resources

Charles Clark Co. "The Urinary System and Its Function," *The Human Organism Series.* #SE7-385, set of 20 slides.

Ward's. *Liquid Waste and the Kidney.* #193 W 1096 U-Matic, #193 W 2096 VHS, or #193 W 3096 Beta II, video tape.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

albuminuria
glycosuria
renal threshold
urinalysis

Review

44. Urinalysis

Name ______________________

Date ______________________

Short answer

1. Describe the physical properties of urine. ______________________

2. Describe albuminuria, what causes it, and how to test for it. ______________________

3. Describe what causes the presence of acetone in urine, and how to test for it. ______________________

4. Describe what causes the presence of sugar in urine, and how to test for it. ______________________

45. Laboratory

Sensory Organs

When you have completed this laboratory you should be able to:

1. Identify the sensory organs of a pig.
2. Identify the major structures of the eye and ear.
3. Identify the major sections of the brain and relate these to function.

The Nervous System

A major distinction between vertebrates and other animals is the highly developed nervous system of the vertebrate. Nervous development goes even further in the mammals, with that part of the brain responsible for intelligence and the ability to adaptively react to the environment especially well developed. The highly specialized vertebrate nervous system consists of far more than a sensory spot or nerve bundle, as was noted in the lower animals. The vertebrate nervous system is composed of both a central and a peripheral network of nerves, as well as highly specialized sensory organs.

The brain and spinal cord constitute the central nervous system, and the nerves that extend from this central system constitute the peripheral nervous system. It consists of sensors and effectors reaching to all parts of the body. The vertebrate body is segmented, and a pair of peripheral nerves is present in each body segment. Those arising from the spinal cord are called spinal nerves and those leaving directly from the brain are known as cranial nerves. Many of the peripheral nerves terminate in receptor cells which can sense such environmental conditions as temperature, pressure, and pH. Some of the cranial nerves go directly to specialized sensory organs such as the eyes, ears, and nose.

In this laboratory you will study the eyes and ears of the fetal pig and how these sensory organs are integrated into the body. You also will observe the general anatomy of the brain. You should remember, as you look at these fetal pig structures, that their names and positions in the body are nearly identical to your own.

Pre-Lab

Supplies needed:

Equipment

dissecting pan
scissors
bone shears
forceps
probe
scalpel
dissecting scope or magnifying glass
small glass dish

Materials

preserved fetal pig

Special Preparations

The supplies needed for this laboratory are the same as those listed originally in laboratory thirty-eight, with the addition of a small glass dish. The dish may be the bottom plate of the dissecting scope. If the student instead is using a magnifying glass, the instructor will need to provide a dish such as half a petri dish. If the student followed directions by labeling and saving the pig, as well as the dissecting equipment, at the conclusion of previous laboratories, no further preparations are necessary.

Time Required

The sensory organs laboratory requires one classroom hour, in addition to preparations, discussion, and review.

Procedure: Hour 1

Students need all listed supplies.

Steps

A. Remove your partially dissected pig from its plastic bag and drain off any accumulated liquid. Cut around an entire eye, starting the incision at the external corner of the eye where the two eyelids touch. Remove the upper and lower eyelids. Note the following structures as you make this incision.

- Conjunctiva: a thin mucous membrane which covers the eyeball and also extends along the under surface of the eyelids.
- Nictitating membrane: also known as a third eyelid. Humans do not have this extra eyelid, which gives additional protection to the pig's eyes. It is a white, half-moon structure to be seen in the inner corner or beneath the lower lid.
- Cornea: this is the clear, transparent covering at the front of the eye. The cornea allows light to enter the eye, and it has been appropriately called the "window of the eye."

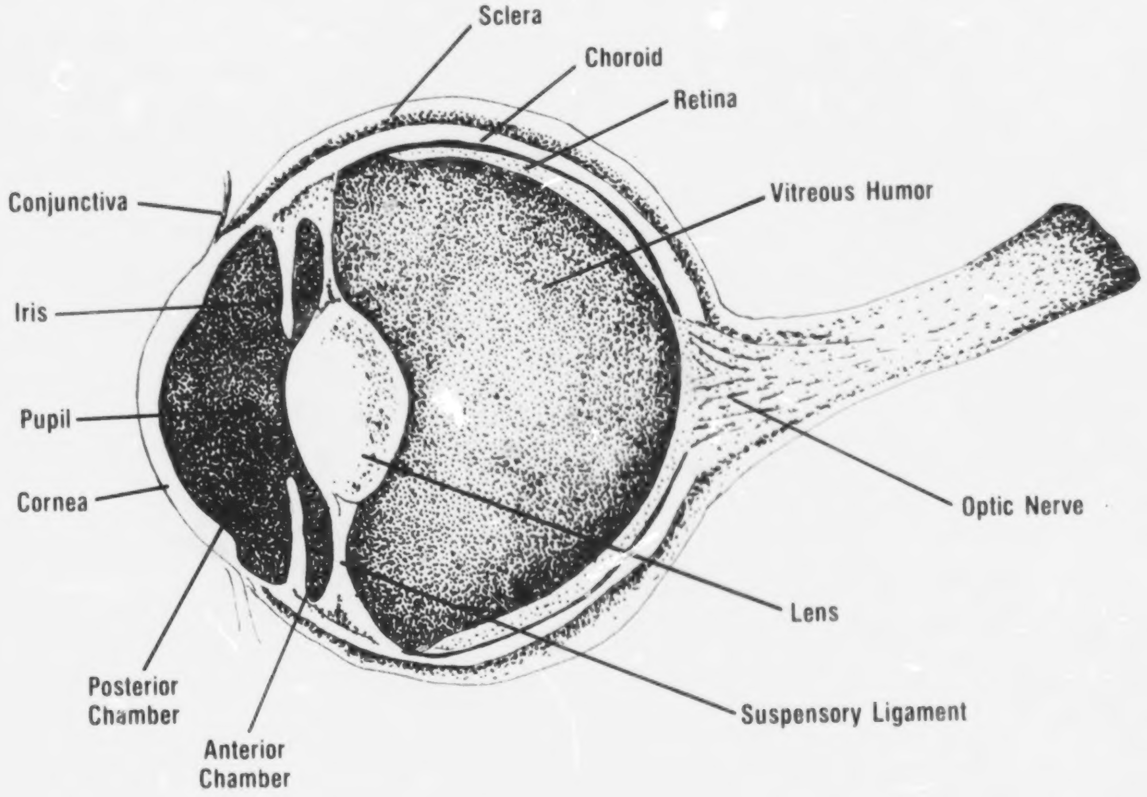
1. Discuss the advantages and disadvantages of the nictitating membrane.

B. You will have to cut part of the bony orbital cavity with your bone shears in order to accomplish this step. Be careful not to destroy the thin straps of muscle attached to the surface of the eyeball as you proceed. Remove the mucous connective tissue and muscles which lie between the eyeball and the surrounding bony cavity. Remove the eyeball from the eye cavity. Note the following structures as you accomplish this step.

- Muscles: seven attached to the eyeball may be seen.
- Optic nerve: this is at the caudal end of the eyeball. You had to cut through this large mass in order to remove the eye from the eye cavity. It is surrounded by a cone-like mass of muscles which serve to pull the eyeball back into the orbital cavity.

2. In the space provided below, draw the eyeball you have removed from your pig. Label all structures listed in steps A and B above, and number the muscles one through seven as they attach to the eyeball. In the space below your drawing, state how you think these muscles move the eyeball in the bony socket of the pig's head (up, down, sideways, in, out, etc.).

C. Using a very sharp scalpel, make a median sagittal incision through the entire eye, except for the lens which is to be left intact. Place the two halves and the lens in a dish with a little water. Study the dissected eye and identify the structures shown in the figure one drawing below.


Sclera
Choroid
Retina
Conjunctiva
Vitreous Humor
Iris
Pupil
Cornea
Optic Nerve
Lens
Posterior Chamber
Anterior Chamber
Suspensory Ligament

Eye Sagittal Section

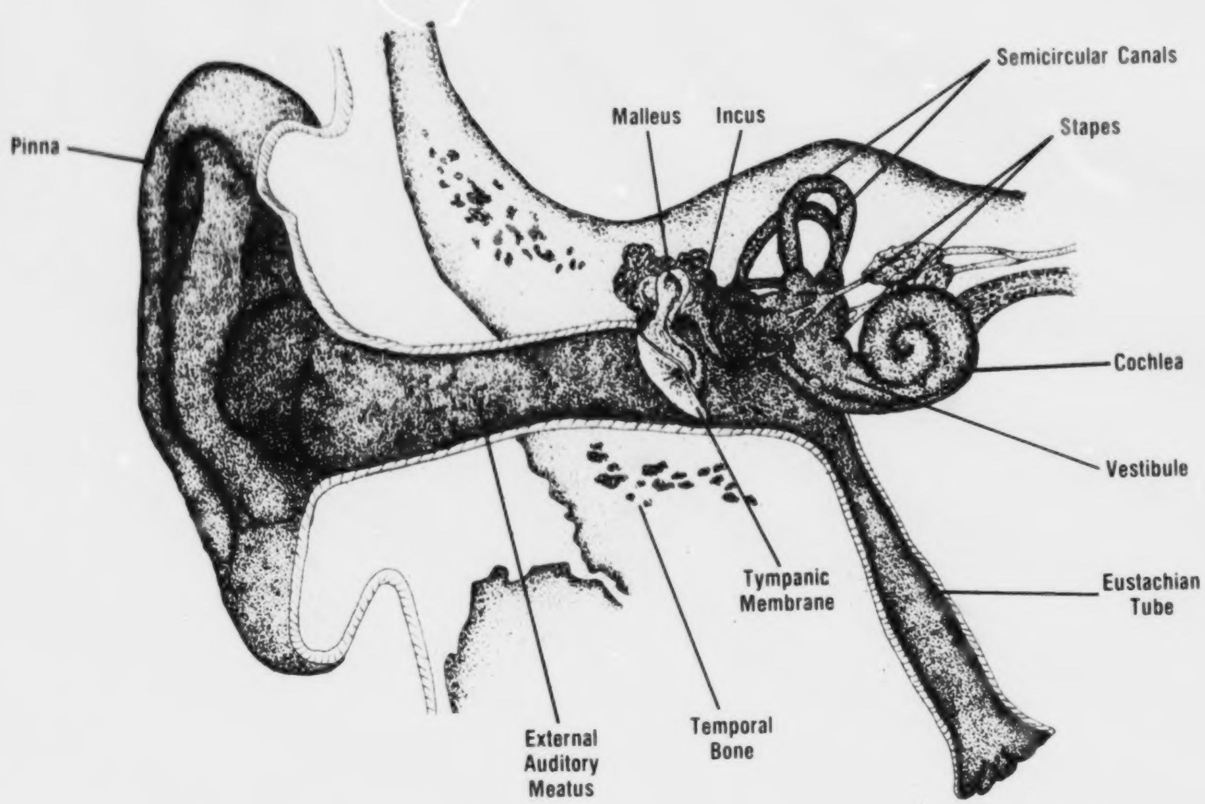
Figure 1

The sclera, labeled in figure one above, is the outer layer of the eye; it is tough, white, and opaque. The choroid is a dark middle layer, and the innermost layer is the retina. The sclera and choroid are protective structures, and the retina contains the microscopic rods and cones which are the visual receptors of the eye. The area of the retina where the optic nerve enters is called the blind spot, since it contains neither rods nor cones.

The anterior and posterior chambers of the eye are filled with a fluid called aqueous humor. The iris, which gives the eye its color and controls the size of the pupil, and hence the amount of light hitting the retina through the pupil, separates the two chambers. The gelatinous material caudal to the eye lens is called vitreous humor.

3. Rinse the eye lens well and dry it gently. Place it over printing such as in this laboratory manual at different levels, and look through the lens at the print. What happens as you change the level of the lens in relation to the print?

D. You will now study the ear. First, study the figure two drawing below and identify the three parts of the ear, the external, middle, and inner ear.


Semicircular Canals
Malleus
Incus
Stapes
Pinna
Cochlea
Vestibule
Tympanic Membrane
Eustachian Tube
External Auditory Meatus
Temporal Bone

Inner Ear

Figure 2

The middle and inner ears are very difficult to dissect properly, and they are best studied in the figure two drawing above. The external ear, however, can be easily observed in dissection. The external ear consists of the visible pinnae and the auditory canal which extends up to the tympanic membrane.

E. Cut off the pinna of one ear close to the head, and locate the external auditory canal. Next, you will have to use bone shears to remove bone in order to remove the skin and muscles surrounding the canal. Continue the dissection until the tympanic membrane is exposed at the end of the canal.

4. What purposes might the pinnae serve on an animal? ______

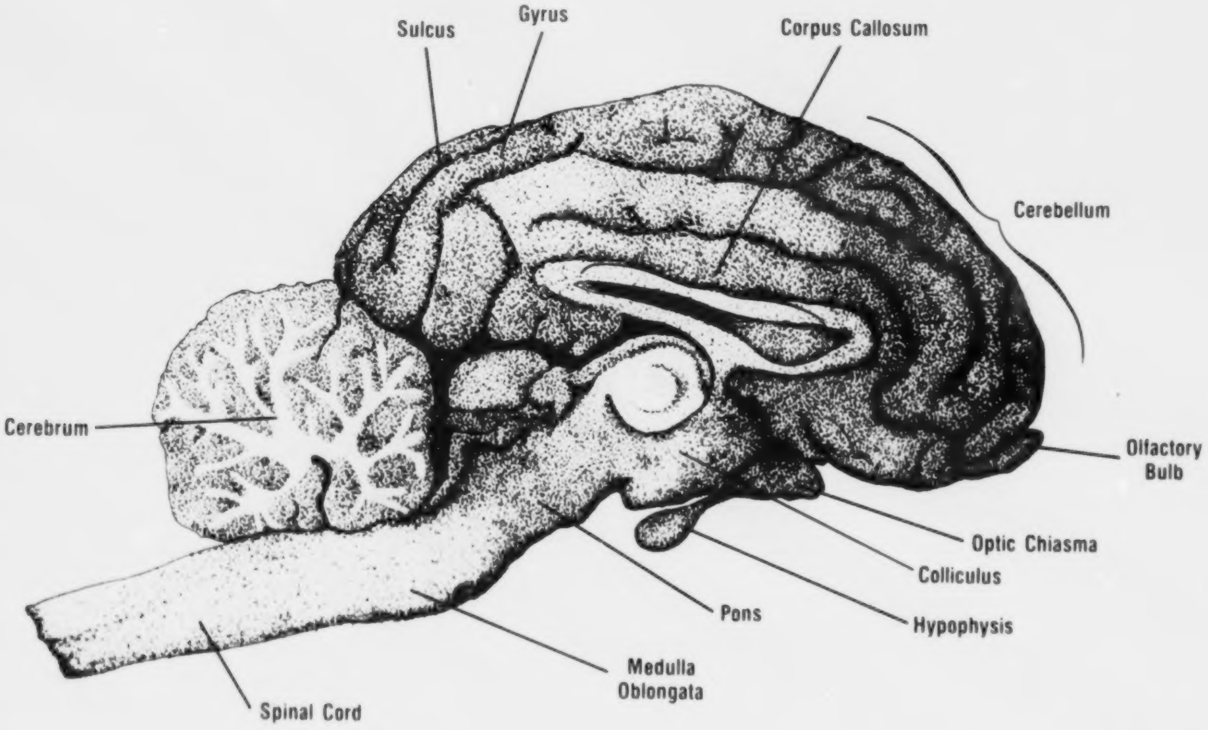
5. Describe the tympanic membrane.

F. You will now study the brain. Make a longitudinal cut through the skin and muscles along the dorsal side of the head, from the base of the snout to the base of the skull. From this incision, make a transverse cut along the jaw angle back to the ears. Remove the skin and bone to expose the skull.

H. The brain can be exposed by removing the skull in small sections. Using the scalpel and bone shears, make a longitudinal cut along the mid-dorsal skull line. You must cut through the bone, but be careful not to squash the soft brain underneath. Make lateral cuts about one inch apart from the longitudinal cut, and chip the bone away as you are able to pry pieces loose. In the caudal region of the brain, where the spinal cord enters, you also will have to cut away heavy neck muscles attached to the brain. Continue until the entire brain is exposed. Lift the brain out of the skull.

NOTE: It is very difficult to accomplish this step without destroying the cranial nerves and hypophysis in the process.

Remove the tough membrane, the dura mater, which lies immediately under the skull. This exposes a thinner and more fragile membrane, the pia mater. A third membrane, the arachnoid, is so delicate that it usually cannot be seen. Identify the parts of the vertebrate brain listed after figure three, using the illustration as an aid to your identifications.



Brain Sagittal Section
Figure 3

- Medulla oblongata: the most posterior part of the brain. Reflex centers in the medulla control respiration, heart rate, the dilation and constriction of blood vessels, swallowing, and vomiting.
- Cerebellum: the size of this part of the brain varies in animals, depending upon the amount of their muscular activity. It regulates muscle contractions. Birds have large cerebella.
- Pons: an area of the hindbrain with nerve fibers which feed into the two hemispheres of the cerebellum. The pons functions as a connective bridge between the two halves of the cerebellum and between the medulla and the midbrain. The pons coordinates muscle movement commands initiated in the cerebellum for the two sides of the body. It also regulates breathing. The medulla oblongata, cerebellum, and pons together constitute the area of the brain known as the hindbrain.
- Midbrain: after the pons, the brain stem narrows into an area known as the midbrain. This section of the pig's brain contains the colliculus, hypophysis, and optic chiasma. The midbrain is responsible for the integration of movements, as well as containing the centers for certain visual and auditory reflexes. Muscle tone and posture are also regulated in the midbrain.
- Colliculus: the superior and inferior colliculi are illustrated in figure three above. The superior colliculus contains visual centers, and the inferior colliculus contains auditory centers.
- Hypophysis: also known as the pituitary gland. It is controlled by the hypothalamus, a brain mass dorsal to it in the pig. The hypothalamus regulates homeostasis in the body, as well as producing sensations of hunger, thirst, pain, pleasure, or sexual drive. Dorsal to the hypothalamus is the thalamus, which is primarily a relay center for sensory impulses. It is known in man as the seat of the emotions.
- Optic chiasma: this is found on the underside of the hypothalamus, and the optic nerves pass through it to enter the brain.
- Cerebrum: it consists of two hemispheres. In the human brain, the cerebrum grows back over the rest of the brain to completely cover the other brain sections. In the pig, the cerebellum is not covered by the cerebrum. The cerebrum houses many sensory control centers. The posterior part directs visual activities, and the temporal lobes direct hearing activities. The motor areas of the cortex, the central part of the cerebrum, control voluntary skeletal muscle activities, among other things. Much of the cerebrum, however, is noted for containing association areas, those areas which provide the animal with the ability to reason, memorize, learn, and imagine.
- Corpus callosum: a white band of nerves and tissue which connects the two hemphispheres of the cerebrum.

6. In the space provided below, draw an exterior view of the brain of your pig in both a dorsal view and a ventral view. Label all structures visible in these views of the brain.

7. The convolutions consisting of the gyrus and sulcus, labeled in figure three, increase the surface area of a brain. What possible advantages are gained by increased brain surface area?

8. Do you think that a human brain would have greater or fewer convolutions than a pig's brain? Why or why not?

9. How does a human brain differ from the pig brain you have dissected?

H. At this point you may dispose of your fetal pig carcass. It has been a useful tool for anatomical study, but you should remember that you have not studied those mammal systems not well-defined in a fetus, namely, the skeletal, muscular, endocrine, and peripheral nervous systems.

Resources

Human Relations Media. *Brain Triggers: Biochemistry and Human Behavior.* #768-00-CSGQ, 3 filmstrips and cassettes.

Human Relations Media. *Exploring the Brain: The Newest Frontier.* #625-00-CSGQ, 5 filmstrips and cassettes.

Scientific American. March 1979. The entire edition is devoted to introducing the latest in research on the brain.

Terminology

Students should understand the following terms and concepts prior to taking the unit review:

- aqueous humor
- blind spot
- cerebrum
- cerebellum
- choroid
- colliculus
- conjunctiva
- cornea
- corpus callosum
- dura mater
- gyrus
- hypophysis
- iris
- medulla oblongata
- nictitating membrane
- optic chiasma
- pia mater
- pons
- pupil
- retina
- sclera
- sulcus
- tympanic membrane
- vitreous humor

Review

45. Sensory Organs

Name ______________________________

Date ______________________________

Fill in the blanks

1. The clear, curved, anterior portion of the eye is known as the ______________________________ .
2. Light enters the eye through an opening called the ______________________________ .
3. The ______________________________ separates the outer ear and the middle ear.
4. The ______________________________ connects the two hemispheres of the cerebrum.
5. The area where the optic nerve enters the retina is known as the ______________________________ .
6. The third eyelid on animals is called a ______________________________ .
7. The ______________________________ contains rods and cones.
8. The anterior chamber of the eye is filled with ______________________________ .
9. The ______________________________ is the tough outer membrane covering the brain.
10. ______________________________ is the name given to the fissures on the surface of the brain.

Essay

Make a diagram of the pig brain. Label the principal parts and list and discuss on the following page the function(s) carried out by each.

46. Exercise

Your Touch Receptors

When you have completed this exercise you should be able to:

1. Understand the functions of skin sensors.
2. Determine your threshold levels for pain and touch.
3. Determine any regularity in perception errors in your touch receptors.

Receptors

The peripheral nervous system allows an animal to sense and respond to conditions in the environment. An organism can survive only if it responds appropriately. Sensing what is required is the function of special receptors in the peripheral nervous system of higher animals.

Mammal eyes and ears, dissected in laboratory forty-five, are examples of such highly specialized receptors. In this exercise, you will study those skin receptors which respond to pain and touch. There are still other skin receptors, including those which sense heat and cold, movement, body position and balance, and weight discrimination. The skin contains a complex mosaic of simple, specialized receptors which in combination serve a wide range of sensory functions. So numerous are the receptors that we are accustomed to regarding the skin surface as a continuum instead of as a mosaic, and, for most practical purposes, the discrete receptors are so numerous, and interact so effectively, that our common notion is not too far wrong. However, each reception point is discrete and limited to one function. The brain requires many of these separate messages before it can interpret conditions accurately.

In some respects, your skin receptors are good objects for study. You can consciously manipulate responses by adjusting timing, spacing, intensity, quality, latency, and duration of stimuli. In another way, testing yourself is not fully satisfactory. Your brain's evaluations derive from stimuli at least three neurons away from the receptors involved. Also, if you are reluctant, consciously or unconsciously, to inflict the smallest amount of discomfort on yourself, you can easily interfere with both the stimuli and their interpretation. You can avoid such distractions by proceeding with the following receptor tests in an objective manner.

NOTE: **This exercise requires that students work in pairs for some of the tests. It also requires access to alcohol, a cotton swab, a pin or needle, a two-point compass, a millimeter ruler (or a compass marked in millimeter increments), a blindfold, and two fine point, felt-tip pens.**

Pain Receptors

Pain receptors in the skin appear to be the free endings of small diameter nerve fibers. These are believed to respond to almost any fairly strong stimulus, such as heat, chemical, or mechanical stimulation. Obtain cotton, alcohol, and a small pin or needle. Sterilize an area of skin on your forearm and explore it carefully with the point of a pin. **Do not draw blood!** Note that it is difficult to find a region which does not respond to this stimulation. On the other hand, even a quick exploration should demonstrate that some regions are more sensitive than others.

1. Where on your forearm were you more sensitive to pain and where were you less sensitive to pain?

____

____

____

2. Explain why these differences exist.

Touch Receptors

The skin surface does not have to be directly touched, or touched that hard, to respond to stimulation. With some of the cotton obtained for skin sterilization, form a very light, loose swab. Blindfold your partner. Stroke a relatively hairless region of your partner's skin with the cotton. Continuously get feed-back on whether the blindfolded partner can feel the cotton swab as you stroke. When you have determined the distinction between response and non-response (feeling and not-feeling the touch), use the highest non-response force on a hairy region of your partner's skin.

3. Is a hairless region of your skin more or less sensitive to touch than a hairy region? Why or why not?

4. Do the nerve endings at the root hairs complement or diminish the responses of the touch receptors in the same area? Why or why not?

Two-Point Thresholds

There are far more receptor endings in the skin than there are sensory nerve fibers leading toward the brain from the skin. This means that many receptors of the same type are served by a single nerve fiber. This also means that accurately determining point of contact is difficult, since interpretation of place of touch can result from any of the endings served by the same fiber. Highly sensitive areas in the skin are supplied with a greater density of both sensory endings and nerve fibers, thus providing greater powers of discrimination in such areas, but these sensitive areas too do not permit discrimination of points of contact within an area served by a single fiber. A point is reached, even in a sensitive area, when multiple touches feel like a single touch.

A crude measure of the surface area served by a single neuron can be taken by using a simple two-point compass. Working in pairs, one partner will be blindfolded and rest an arm on a table, with the inner surface of the arm facing up. The partner without a blindfold will touch, with the compass points, the skin on the inner surface of the resting forearm of the blindfolded partner. The toucher will randomly mix the use of one and two compass points, as he or she chooses. The toucher will place the tip/tips on the skin with a gentle, even pressure, and remove the tip/tips within one second, placing and removing both points simultaneously, if a two-point touch is being used.

The blindfolded partner is to say "single" or "double" to each touch. The toucher is not to tell the partner whether or not their response is correct but is simply to record each touch and response, as explained below. The toucher is to use a mixture of single and double touches at each of different separations of the compass points. Since the two-point threshold, the point when a two-point touch can be correctly identified at least half the time, falls within the range of four to eighteen millimeters, for most people, most tests should be made in this range, in increments separated by two millimeters. Adjust the separation of the compass points and continue testing until the blindfolded partner's two-point threshold can be determined. Above that separation, accuracy will increase until every double touch is correctly identified, and below that separation, accuracy will decrease until every double touch will feel like a single-point touch.

5. Fill in the chart, figure one below, with touch results. Write in each cell below a particular compass separation distance whether the touch was with one or two points, and whether the blindfolded partner's response was correct or not. The cells, accordingly, will be marked with 1y (one-point touch, correctly identified), 1n (one-point touch, incorrectly identified), 2y, and 2n. Not all cells need to be filled. Continue testing only until the two-point threshold, the all-right, and the all-wrong two-point separation distances have been determined.

TWO-POINT SKIN THRESHOLDS

Distance Between Compass Points in Millimeters									
2	4	6	8	10	12	14	16	18	20

Figure 1

6. Reverse positions of the blindfolded partner and toucher, and repeat the experiment, filling out the other person's chart and determining their two-point threshold, as well as their all-right and all-wrong separation distances. For some it may be necessary to choose different millimeter separations than those listed in the above chart. If so, change the column headings to the correct millimeter separations.

7. How might the following individual differences affect responses to the two-point threshold tests?

Genetic inheritance ____

____

Amount of musculature ____

____

Deep tan or sunburn ____

____

Amount of fat ____

____

You may have noted that transitions between extremes, that is, when all touches are correctly identified and when all double touches are incorrectly identified, can be quite consistent. This can be graphed.

8. Calculate the percentages for accurate responses recorded in the figure one chart, and write those percentages in figure two below.

Distance between Compass Points in Millimeters											
% of 1-Point Touches Correctly Identified											
% of 2-Point Touches Correctly Identified											

Figure 2

9. Plot the percentages calculated and written above in figure two, by placing, in the following figure three, a dot for each percentage, and joining those dots with a line. This should yield two lines, one for correct one-point responses and one for correct two-point responses. Where these two lines cross will graphically demonstrate the two-point threshold for that individual.

1-Point Touch Percentage

2-Point Touch Percentage

100											**100**
90											**90**
80											**80**
70											**70**
60											**60**
50											**50**
40											**40**
30											**30**
20											**20**
10											**10**
0											**0**
Distance	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**Distance**

Figure 3

10. At what distance does your two-point threshold occur? ______________________

11. How would you verbally describe this point?

12. Name areas of the body which you think may be more and which may be less sensitive to touch than the inner forearm. Why does this difference exist?

Regularity in Tactile Errors

The two-point threshold for the inner forearm, as calculated above, was a rough measure of the area served by one neuron in that part of the body. Still other aspects of touch can be demonstrated. For example, the average person relies more heavily on visual perception than touch (tactile) perception, partly because tactile perception has innate error margins. This error factor tends to be consistent in the same way in the same individual.

You will again work in pairs, with one subject blindfolded. When the test of the blindfolded partner is complete, positions will be reversed and the test repeated. You will require one blindfold and two fine point, felt-tip pens (or ballpoint pens which will write on the skin).

Blindfold one partner, select the ball of one fingertip as the area for testing, and place a felt-tip pen in the testee's other hand. The toucher/examiner also is to pick up a pen and touch a spot on the selected fingertip ball. Touch hard and long enough to leave an ink mark.

The blindfolded partner immediately is to attempt to place the tip of their pen on the identical point on their fingertip ball. One correction movement is allowed as the blindfolded partner reaches with one hand over to a fingertip ball on the other hand. This partner also is to leave an ink mark. The observer will study the marks and, when they are different, is to draw a line connecting the two, distinguishing between the first and second marks by placing an arrowhead next to the second mark along the line connecting the two points.

Continue exploring the entire fingertip ball, proceeding slightly down the sides of the finger if necessary to complete at least five more tests on the same fingertip ball.

13. Reproduce the map created during this study of your fingertip ball in the space provided below. Draw the fingertip ball, points, lines, and arrowheads.

14. Was there a pattern of error in your tactile perception and recall? If so, describe. ______________________

____

____

____

There occasionally will be that rare individual who has the tactile agility and recall which allows them to nearly always touch the same spot.

15. There are many other types of skin receptors, as noted earlier. Briefly describe how you might safely test for one other tactile response.

____

____

____

____

____

Most people are less conscious of touch receptor responses than the messages received from other sensors. This, however, dramatically changes for the blind who must compensate for their lack of vision. If there is a vision-impaired member of your family, you might consider repeating the above tests on them. You likely will be greatly surprised about the degree to which they have increased their sensitivity to touch, as compared to your relatively neglected tactile sensitivity.

Resources

Tinker, Robert F. *Experiments in Human Physiology*. #502-00-MSAG, 1 Apple computer diskette, interface box, probes, timer, plug, sensor, cables, and teaching guide. Available from Human Resources Media.

Review

46. Your Touch Receptors

Name ______________________________

Date ______________________________

Short answer

1. Describe threshold levels in skin touch receptors. ______________________________

2. How do nerve fiber endings on hair follicles affect the threshold levels for touch receptors in the same area?

3. What is the difference between a pain receptor and a touch receptor? ______________________________

4. Name five common sensory receptors of the skin. ______________________________

Appendix A:

Glossary

Abiotic: not living.

Acid: hydrogen ion containing molecule, or a substance able to accept an unshared pair of electrons from a base.

Active Transport: movement of a substance through a semi-permeable membrane against, or in opposition to the concentration gradient.

Adenine: purine base, one of the nitrogenous bases in DNA and RNA.

Adenosine Tri-phosphate (ATP): organic compound which fuels the life processes of all cells by storing and releasing energy in a high energy phosphate bond.

Adjustment: knobs on a microscope used to focus on a specimen, with the fine adjustment knob used for sharp focus and the coarse adjustment knob for rapid focus.

Adrenal Glands: endocrine glands located on the anterior ends of the kidneys in most vertebrates. The adrenal glands secrete adrenalin, as well as steroids.

Aerobic: with oxygen.

Agar: extract of algae used as a medium to culture bacteria, and also as a thickener and gel in the food industry.

Albuminuria: excess albumin, a protein, in urine excretions.

Alkane: open-chained hydrocarbon with all carbons bonded singly. Also called saturated hydrocarbon because it structurally contains the most hydrogen atoms possible.

Alkene: open-chained hydrocarbon which contains at least one double carbon bond.

Alkyne: open-chained hydrocarbon which contains at least one triple carbon bond.

Allele: one of a pair of genes that resides at a given locus on a chromosome. Also, either of a pair of alternate Mendelian characteristics for a single trait.

Alternation of Generations: in animals, reproducing asexually and sexually in alternating phases. One asexually produces the other, and that offspring then sexually reproduces an organism like the original. Two different body plans are involved during the two generations. In plants, alternation of generations is a simple shift between haploid and diploid generations.

Ambulacral Groove: structure on the radial areas of echinoderms, such as the arms of starfish, along which run the principal structures of the water vascular system.

Amino Acid: any small organic acid containing the amino group NH_2. Amino acids are the chief constituents of proteins.

Amoeba: genus of *Sarcodina*. Protozoa which move by pseudopodia.

Amoebocyte: amoeba-like cells found in the mesoglea of sponges which function in the digestion, reproduction, and structural maintenance of the sponge.

Amphibian: "dual-lived" vertebrates, those which must live part of their lives in water, of the class *Amphibia*. Examples are frogs, toads, newts, and salamanders.

Amplexus: sexual embrace of a male frog with a female which causes her to lay eggs.

Ampulla: in echinoderms, knob-like structures which terminate the internal end of the animal's tube feet and which provide suction power by muscular contractions that create hydrostatic pressure.

Anaerobic: without oxygen.

Annelida: phylum of segmented roundworms.

Aorta: the great arterial trunk which carries blood from the heart to the arterial system of an animal.

Aortic Arch: enlarged branch of a closed circulatory system. In the *Annelida*, five arches serve as an organ to pump blood throughout the animal. In vertebrate embryos, arches connect ventral and dorsal arterial systems; these arches persist in adult fishes but are highly modified in other vertebrates.

Apoenzyme: protein that forms an active enzyme system by combination with a coenzyme which determines the specificity of the system for a substrate.

Aqueous Humor: fluid which fills the anterior and posterior chambers of the eye.

Arm: on a microscope, that part which attaches the tube to the base.

Artery: any of the tubular, muscular branching vessels which carry oxygenated blood from the heart to the body.

Arthropoda: phylum of invertebrates characterized by jointed appendages and chitinous exoskeletons. It includes the insects, crustaceans, spiders, centipedes, and millipedes.

Ascaris: genus of unsegmented roundworms, class *Nematoda*, which are intestinal parasites common in man.

Asteroidea: class of *Echinodermata* which includes the starfish.

Atrium: chamber or chambers of the heart which receives blood from the veins and forces it into the ventricles of the heart for pumping.

Auricle: chemoreceptors, or olfactory receptors, of a planaria.

Australopithecus: any of a genus of near-human hominids with small brains, bipedalism, and human-like tooth structure.

Autosome: any chromosome other than a sex chromosome.

Autotroph: any organism capable of converting the sun's energy into chemical energy usable by a cell.

Bacillus: rod-shaped bacterium.

Backbone: flexible, usually bony support that develops around the notochord and encircles the nerve cord along the length of the spine in vertebrates. In most higher vertebrates, the backbone completely supplants the notochord.

Basal Disc: point of attachment of a coelenterate body to a surface.

Base: in chemistry, a hydroxide ion containing molecule, or a substance able to donate an unshared pair of electrons to an acid.

Base: in the structure of DNA and RNA molecules, a protein which has a basic pH and which, with a sugar and a phosphate, composes the nucleotide building blocks.

Base: on a microscope, the bottom.

Bicuspid Valve: valve lying between the left atrium and ventricle in the heart and which consists of two flaps of tissue called cusps (also referred to as the mitral valve).

Bilateral Symmetry: where the two sides of an organism are mirror images of each other.

Biotic: living.

Blind Spot: area of the retina where the optic nerve enters. There are no rods or cones for visual reception in this part of the retina.

Blood Type: one of the classes into which human blood can be distinguished on the basis of the presence or absence of specific antigens.

Broca's Area: center for speech in the human brain.

Buccal Cavity: mouth cavity of an earthworm.

Budding: form of asexual reproduction in lower organisms during which a ball or small miniature of the organism is cloned near the base, after which it breaks off to become a separate individual.

Buffer: any substance which resists changes in pH with the addition of either acids or bases.

Calciferous Gland: glands connected to the esophagus of an earthworm which secrete calcium into acidic food.

Calorie: as used by scientists, the amount of energy required to heat one gram of water one degree centigrade; as used by nutritionists, the energy unit for food which is equivalent to one thousand scientific calories.

Carapace: fused head and thoracic exoskeleton of arthropods, such as the crayfish.

Carbohydrate: major class of animal foods which are composed solely of carbon, hydrogen, and oxygen in a 1:2:1 ratio, unless the ratio has been altered by a dehydration synthesis. Sugars, starches, and celluloses are examples of carbohydrates.

Carcinogen: any cancer causing compound.

Carnivore: flesh-eating animal.

Cell Membrane: plasma membrane which surrounds and encloses the contents of all eukaryotic cells. In plant cells, a middle lamella separates the interior cell membrane from the exterior cell wall.

Cell Wall: in plants, a stiff, usually cellulose exterior structure which surrounds and encloses all other cellular contents.

Cellulose: carbohydrate of high molecular weight used by plants to provide rigidity.

Central Disc: in echinoderms, the central part of the body from which radiate the appendages, usually five-parted, as in starfish.

Cerebellum: dorsal portion of the brain that is concerned with the coordination of muscles and maintenance of bodily equilibrium.

Cerebrum: anterior portion of the brain that in higher mammals overlies the rest of the brain and which is considered to be the seat of conscious mental processes.

Cervical Groove: indentation in the carapace which differentiates the head and thoracic regions of crustaceans.

Cheliped: large maxilliped ("front claws") of a crustacean, used for food-getting and protection.

Chitin: carbohydrate of high molecular weight used by animals such as the *Arthropoda* and *Crustacea* for support in exoskeletons.

Chlorophyll: photosynthetic pigment found in all autotrophs.

Chloroplast: in most photosynthetic plants, the organelle which contains the photosynthetic pigment chlorophyll.

Choanocyte: sponge collar cells which line the interior cavity and function in food-getting, digestion, and water flow.

Chondrichthyes: class of vertebrates containing the sharks, skates, and rays.

Chordata: phylum of animals which possess a notochord.

Choroid: membrane containing large, dark pigment cells which is located between the retina and the sclera of the vertebrate eye.

Cilia: small thread-like projections used for locomotion by a class of protoza called the ciliates. Hundreds of cilia covering the outside of a unicellular organism beat in wave-like unison, propelling the organism. Ciliated cells also are found in multicellular organisms, such as the esophagus lining of man.

Ciliata: class of protozoa characterized by the use of cilia for locomotion.

Clitellum: thickened section of an earthworm body wall that secretes a cocoon in which eggs are deposited.

Cloaca: common sac of the digestive, excretory, and reproductive tracts of a frog. The cloaca opens externally through the anus of the animal.

Coccus: round-shaped bacterium.

Codon: any group of three nucleotides in the genetic code which specify a particular amino acid to be used in a protein, or which specify the start or stop points for protein synthesis.

Coelenterata: phylum of invertebrate animals characterized by two body layers, radial symmetry, a gastrovascular cavity, and stinging nematocysts. They include jellyfish, corals, sea anemones, and hydroids.

Coelum: body cavity. A coelom, or eucoelom, lies within tissues of mesodermal origin, and it surrounds a gastrodermis covered with mesodermal tissues.

Coenzyme: non-protein compound that forms the active portion of an enzyme system after combination with an apoenzyme.

Colliculus: part of the vertebrate midbrain. The superior colliculus contains visual centers, and the inferior colliculus contains auditory centers.

Colloids: solute particles whose molecular diameters are relatively large, such as starch and proteins.

Concentration Gradient: difference in solute concentration ranging from higher to lower.

Conjugation: sexual reproduction in the *Ciliata*. Also, a form of sexual reproduction in bacteria.

Conjunctiva: mucous-like covering of the inner eyelids and eyeball.

Cornea: transparent front part of the eye that covers the iris and pupil and admits light to the interior of the eye.

Corpus Callosum: a great band of nerves and fibers that units the two hemispheres of the brain in man and higher mammals.

Covalent: non-ionic bond formed by shared electrons.

Cro Magnon: form of *Homo sapiens* which populated primarily Southern France until the last great ice age.

Crop: storage organ for food at the end of the esophagus. Crops are found in all birds and earthworms, as well as in some insects.

Crustacea: class in the phylum *Arthropoda* which includes the crabs, lobsters, and shrimps.

Crystalloids: solute particles whose molecular diameters are small, such as glucose.

Ctenoid Scale: small, flattened, rigid plate forming part of the protective covering of some animals, especially fish. A ctenoid scale is typical of fish such as perch and bass and is characterized by a toothed or rough margin.

Ctenophora: phylum of invertebrate animals characterized by two body layers and bilateral symmetry, with fused cilia for locomotion. They are commonly known as the combed jellies.

Cytosine: pyrimidine base, one the nitrogenous bases in DNA and RNA.

Darwin: Erasmus, the grandfather, and Charles, author of *On the Origin of Species*, formulated many of the basic theoretical ideas of evolution.

Dehydration Synthesis: forming of larger molecules from smaller ones through the removal of water molecules.

Deoxyribonucleic Acid (DNA): nucleic acid, found in the nucleus of eukaryotic cells, which transfers information from parent to offspring and also serves as a storehouse of information for cellular function.

Deuterostome: embryological development characteristic of echinoderms and vertebrates in which the anus is formed from the lip of the blastophore stage and the mouth is formed secondarily.

Dialysis: diffusion of crystalloids but not colloids through a semi-permeable membrane.

Diaphragm: on a microscope, the part which controls the amount of light that strikes a specimen and which is usually located under the stage.

Diaphragm: in a mammal, a muscular sheet which separates the thoracic cavity containing the heart and lungs from the abdominal cavity containing the intestines, stomach, and other digestive/excretory organs.

Dichotomous Key: system of two-part questions used to analyze and classify organisms.

Diffusion: molecules moving from an area of higher concentration to an area of lower concentration. This movement of molecules continues until a state of equilibrium is achieved.

Dihybrid: mating in which the parents differ with respect to two different alleles, or traits.

Disaccharide: any sugar which yields upon hydrolysis two monosaccharide molecules, sucrose being an example.

Dissociate: in chemistry, when an ion, atom, or molecule separates into smaller parts.

Diverticulum: dead end of the intestinal tract of those animals without an anus.

Ductus Arteriosus: a short, broad vessel in the fetus which connects the pulmonary artery with the aorta and conducts blood directly from the right ventricle to the aorta, bypassing the non-functioning fetal lungs.

Duodenum: upper section of the small intestine.

Dura Mater: tough outer membrane covering the brain.

Earthworm: terrestrial annelid worm, class *Oligochaeta*.

Echinodermata: phylum of invertebrates characterized by adult radial symmetry, an endoskeleton, and a water vascular system.

Ecosystem: complex of plant and animal communities in an area as they function in their environment.

Ectoparasite: parasite which attaches itself to the outside of a host, usually with suckers.

Egg: female gamete.

Electron Microscope: microscope which uses a beam of electrons focused through a magnetic field to magnify the specimen.

Endodermis: internal layer of cell tissue.

Endoparasite: internal parasite, such as those which live in the digestive tract or muscles of a host.

Endoskeleton internal skeleton or supporting framework for an animal.

Enzyme: complex protein produced by living cells which acts as a catalyst for specific biochemical reactions. Like inorganic catalysts, enzymes affect the rate of a reaction while not being used-up themselves.

Epidemic: rapid growth and spread, such as a disease.

Epidermis: external layer of cell tissue.

Esophagus: muscular tube which connects the pharynx with the stomach and through which food passes.

Ester: any of a group of molecules formed by the dehydration synthesis reaction of an acid and an alcohol. Esters are of lower molecular weight than lipids, which are formed from the same types of reactions. Esters provide odors and solvents.

Estivation: physical and metabolic inactivity of some animals brought about by the heat of summer. Frogs usually estivate in mud at the bottom of ponds.

Euglena: genus of *Mastigophora*.

Eukaryote: considered to be a "true" cell which contains organelles such as a nucleus, mitochondria, and golgi bodies.

Exoskeleton: external skeleton or supporting framework for an animal, such as mollusc shells.

Eyepiece: on a microscope, the lens through which a specimen is viewed.

Eyespot: light sensitive area on a planaria.

Facilitated Diffusion: carrier-mediated diffusion in which passive diffusion along a concentration gradient is aided by an outside agent.

Facultative Anaerobe: organisms which can respire with or without oxygen.

Fermentation: respiration in the absence of oxygen. The by-products of fermentation are mostly alcohol or acetic acid.

Field of View: on a microscope, the area under focus.

Filial Generation: a generation in a breeding experiment that is successive to a parental generation. F_1 (first filial) is the first such generation, F_2 (second filial) is the second, etc.

Fission: asexual reproduction characterized by simple division of one cell into two identical daughter cells.

Flagella: long thread-like cytoplasmic projections used for locomotion by members of the protozoan class *Mastigophora*. Individuals may possess one or more flagella.

Fluke: the common name for organisms in the class *Trematoda* of the *Platyhelminthes*. Most flukes are ectoparasites, that is, they attach to the outside of a host or organ with suckers where they feed on the host's tissue or blood.

Focus: on a microscope, how clearly or sharply the specimen is seen.

Food Group: category of foods which have similar nutrients, e.g. milk, fruits, vegetables, etc.

Foot: terminal part of the leg of a vertebrate. Also, an invertebrate organ of locomotion or attachment, such as in the molluscs.

Functional Group: in chemistry, the part of a molecule which determines certain reactive properties of the molecule.

Gas Bladder: sac in bony fishes used variously as a hydrostatic organ and as a reserve oxygen source. It is theorized that gas bladders developed from primitive lungs.

Gastric Mill: structure with three teeth, used for grinding, located between the cardiac and pyloric stomachs of a crustacean.

Gemmule: form of asexual reproduction in sponges, especially in freshwater sponges. The gemmule is a clump of sponge cells encased in a protective covering. When the parent sponge dies and decays, gemmules are released into the water to become new individuals.

Genotype: actual genetic make-up of an individual.

Gill Slit: openings, usually five per side, leading to the gills of the *Chondrichthyes*.

Gizzard: tough, muscular organ which follows the crop in the digestive tract of birds, some insects, and earthworms. Gizzards hold sand, grit, or even small rocks, and food is coarsely ground in them in preparation for its entrance into the intestine.

Glycogen: primary storage form of carbohydrates in animal tissue.

Glycosuria: excess glucose in urine excretions.

Green Gland: kidneys of a crustacean.

Guanine: purine base, one of the nitrogenous bases in DNA and RNA.

Gubernaculum: tough, white ligament which holds the testes in place in the scrotal sac.

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Gyrus: convoluted ridge between grooves, as on the brain's surface.

Herbivore: plant-eating animal.

Heterogamete: gametes unlike in size and appearance.

Heterotroph: any organism which must feed, or consume organic nutrients, in order to obtain cellular energy.

Heterozygous: belonging to a diploid organism which has different alleles for a given trait.

Hibernation: physical and metabolic inactivity of some animals brought about by the cold of winter. Frogs usually hibernate in mud at the bottom of ponds, and bears in caves or other natural holes.

Homotherm: warm-blooded animal.

Homo erectus: primitive man who emerged at least one and a half million years ago and whose remains are found in many parts of the world. He was more massively built than modern man, with a longer, flatter skull, and a protruding brow ridge.

Homo habilis: primitive man who emerged nearly three million years ago and who was discovered by Louis Leakey in 1962. *Homo habilis* was so named because it is thought that he might be the first species of primitive man to both use and make tools.

Homo sapiens: modern man.

Homozygous: belonging to a diploid organism which has identical alleles for a given trait. An organism may be homozygous with respect to some traits and heterozygous with respect to others.

Hookworm: genus of unsegmented roundworms, class *Nematoda*, which are intestinal parasites of man. They are acquired by direct contact with worm infested soil.

Humus: organic components of soil.

Hydra: genus of fresh water coelenterates characterized during the polyp generation by a tubular body having a mouth with tentacles at one end.

Hydrocarbon: organic compound containing only hydrogen and carbon.

Hydrolysis: decomposition of a molecule by splitting a chemical bond through the addition of water.

Hyoid Apparatus: bone which supports the tongue and its muscles.

Hypophysis: also known as the pituitary, or master gland. It controls the endocrine system, under direction from the hypothalamus.

Ileum: coiled, lower part of the small intestine.

Ileocaecal Valve: muscular valve separating the ileum and the colon. The valve controls the flow of undigested food into the large intestine.

Incomplete Dominance: when neither allele of a chromosome pair dominates the other.

Indicator: in science, a dye which is one color in an acid solution, and another color in a base solution.

Inguinal Canal: "opening" between the scrotal sac and the abdominal cavity through which the spermatic duct passes.

Interkinesis: critical stage in meiosis during which cells prepare to divide without replicating DNA or duplicating chromosomes.

Interphase: interval in the life of a cell between the end of one mitotic or meiotic division and start of another. Chromosomes duplicate toward the end of this phase.

Iris: colored portion of the eye which controls opening and closing of the pupil, thus regulating the amount of light which strikes the receptor rods and cones of the retina.

Isogamete: gametes which are alike in size and appearance.

Jejunum: middle portion of the small intestine.

Koch: Robert, a German biologist who devised bacteria culturing techniques.

Labial Palp: a clam's lip.

Larynx: also known as the voice box. In mammals located at the upper end of the trachea and composed of four cartilaginous rings, the upper one being the epiglottis and the larger one providing support for the thyroid gland.

Lateral Line: sense organ in sharks and fishes which detects water pressure and low vibrations. In sharks and some fishes, the lateral line also senses electrical fields.

Leucoplast: starch storage organelle, or plastid, of many plant cells.

Lipid: fats, oils, and waxes. They are formed by the dehydration synthesis of fatty acids with glycerol.

Madreporite: hard, sieve-like structure on the dorsal side of a starfish through which water is sucked into the water vascular system.

Mammal: class *Mammalia*, sub-phylum *Vertebrata*, characterized by mammary glands and hair.

Mandible: animal's lower jawbone, or the lateral appendages on the mouths of crustaceans.

Mantle: fold or lobe, or pair of lobes, of the body wall of a mollusc which lines the shell and which contains glands which secrete the shell.

Marsupial: type of mammal without a true placenta which carries its young in a pouch on the female abdomen.

Mastigophora: class of protozoa characterized by the use of flagella for locomotion.

Maxilla: animal's upper jawbone, or the first or second mouth parts posterior to the mandibles in many arthropods.

Medulla Oblongata: most porterior part of the brain. Reflex centers in the medulla control respiration, heart rate, dilation and constriction of blood vessels, swallowing, and vomiting.

Medusa: jellyfish body plan typical of one generation in the life cycle of coelenterates.

Mendel: Gregor, an Augustinian monk known as the "Father of Genetics."

Mesentery: tissue originating from the peritoneum of the dorsal wall of the abdominal cavity which supports abdominal organs.

Mesodermis: middle, or third, cell layer in multicellular organisms.

Mesoglea: gelatinous matrix in sponges and coelenterates which divides the endodermis from the epidermis. The mesoglea is not a true third cell layer, in that it is composed of unorganized gelatinous material. Cells embedded in the mesoglea perform specialized functions.

Messenger RNA (mRNA): a nucleic acid, formed by DNA in the nucleus of a cell, which transmits messages from DNA to the cell's cytoplasm.

Metamerism: condition of having a body made up of repeating structures or segments.

Metaphase: phase in mitosis in which the chromosomes line up across the equator of the cell.

Micron ( ): unit of measurement equal to one millionth of a meter.

Mollusca: phylum of soft-bodied, usually shelled animals which move by means of a foot and which have a radula surrounding the tongue. The phylum includes clams, oysters, snails, etc.

Monohybrid: mating in which the parents differ with respect to one different allele, or trait.

Monosaccharide: simple sugar composed of five or six carbons, hydrogen, and oxygen in a 1:2:1 ratio.

Monotreme: egg-laying mammal.

Mutation: any change in the codons that compose the genes.

Natural Selection: ongoing evolutionary process, in which members of a species whose modifications suit their environment survive, and those whose modifications place them at a disadvantage die off.

Neanderthal: a form of *Homo sapiens* first discovered in the Neander Valley of Germany. His remains have been found throughout Europe, Northern Africa, and Western Asia.

Nemathelminthes: phylum of unsegmented roundworms.

Nematocyst: stinging structure of coelenterates found in cnidoblast cells on the tentacles.

Nematoda: class of roundworms in the phylum *Nemathelminthes*.

Neoteny: in evolution, when the descendants look like the juveniles of their ancestors.

Nephridia: primary excretory structure of many invertebrates.

Net Diffusion: movement of more particles of a substance in one direction rather than in the opposite direction. Net diffusion occurs down a concentration gradient.

Nictitating Membrane: semi-transparent lower eyelid of some water dwelling animals, such as frogs and waterfowl. Also present in the pig and other burrowing animals. The nictitating membrane protects the eye while allowing the animal to see under water or while digging.

Nondisjunction: when a chromosome pair does not properly separate during cell division.

Notochord: dorsal, longitudinal rod which is firm yet flexible, and which forms the supporting axis of an animal's body.

Nucleoprotein: molecule composed of a protein conjugated with a nucleic acid. Nucleoproteins are the principle constituents of the hereditary material in chromosomes.

Nucleotide: basic unit of DNA and RNA. It is composed of a sugar, a phosphate, and a nitrogenous base.

Nucleus: control organelle of a eukaryotic cell. The nucleus contains the hereditary information vital to the function and reproduction of the cell.

Objective: on a microscope, the lens used to magnify the specimen. The low power objective is used to scan a field of view, while the high power objective is used for observation in detail.

Omnivore: animal, such as pig and human, that eats both meat and plants.

Oogenesis: formation and maturation of an egg.

Ootid: egg cell immediately after meiosis.

Operculum: bony covering of the gills of bony fishes.

Optic Chiasma: part of the brain located on the underside of the hypothalamus. Optic nerves enter the brain here.

Organelle: organized cellular inclusions found in all eukaryotic cells.

Organic Compound: any compound which contains carbon.

Oscula: large outcurrent pores of a sponge.

Osteichthyes: class of bony fishes.

Ostia: incurrent pores of a sponge.

Ovoviviparous: reproductive condition in which eggs are laid but carried internally by the mother until hatching.

Paper Chromatography: chemical separation technique which employs paper strips and a solvent which carries various chemicals different distances along the strips, depending upon a given chemical's dissolvability in the solvent and its relative molecular weight.

Paramecium: genus of *Ciliata*. Protozoa which move by cilia.

Parthenogenesis: ability of unfertilized gametes to divide, grow, and develop into mature individuals.

Pasteurization: heating of a food or drink sufficiently to kill any living organisms, without any major alterations to the food or drink. Commonly used with milk and milk products.

Pedicillariae: microscopic pincers clustered around the bases of echinoderm spines. They keep at bay organisms which might otherwise attach to the animal.

Pelecypoda: meaning "hatchet footed." The class of *Mollusca* characterized by having a well developed hatchet shaped foot and two valves, or parts to their shells.

Pellicle: outer membrane of some protozoa.

Penis: male organ of copulation and excretion.

Peptide Bond: chemical bond between nitrogen and carbon.

Perca flavescens: yellow perch.

Pericardial Sac: sac or tissue surrounding and enclosing the heart.

Periodic Table: Arrangement of chemical elements, based upon the order of their atomic numbers, which shows a periodic variation in their physical properties.

Peristalsis: wave-like muscular motion which forces food through the digestive tract of vertebrates.

Peristome: membranous area around the mouth of a starfish.

Peritoneum: tissue which lines the abdominal cavity.

pH: scale to measure changes in acidity and basicity, which runs from zero to fourteen, with seven representing neutrality. Acids run from 0 to 6.9 and bases from 7.1 to 14.

Pharynx: muscular throat area in animals used for swallowing food.

Phenotype: observable traits of an individual

Pia Mater: middle membrane covering the brain.

Pinworm: genus of unsegmented roundworms, class *Nematoda*, which parasitize man. Entry normally is through the mouth, and children who play in contaminated dirt or sandboxes are at risk.

Placental Mammal: mammal which carries and nourishes its young inside the uterus. The young are attached by an umbilical cord to a membranous structure called a placenta, which interfaces with the bloodstream of the mother to provide nutrients, gas exchange, and waste removal for the fetus.

Placoid Scale: tooth-like scale representative of ancient placoid fishes, as well as present day sharks.

Planaria: order of free-living flatworms in the phylum *Platyhelminthes*.

Plasmodium: genus of *Sporozoa*. Parasitic protozoa which have no means of locomotion.

Plastid: organized plant organelles.

Platyhelminthes: phylum for flatworms, the simplest animals with three cell layers, developed organ systems, and a brain.

Pleural Cavity: part of the chest cavity containing the lungs.

Polymerization: chemical reaction in which two or more small molecules combine to form larger molecules that contain repeating structural units of the original molecules.

Polyp: tubular body plan, typical of one phase in the life cycle of coelenterates. Polyps typically are sessile at one end and endowed with a mouth and tentacles at the other end.

Polysaccharide: three or more monosaccharides bonded together. Examples are starch, glycogen, and cellulose.

Pons: area of the hindbrain containing nerve fibers linking the two hemispheres of the cerebellum, as well as the hindbrain and midbrain. The pons coordinates muscle movements and regulates breathing.

Porifera: phylum of multicellular animals, commonly called sponges, which are characterized by pores or holes in the body wall.

Proglottid: term for the body segments of tapeworms in the class *Cestoda*.

Prokaryote: cell which has no organelles. Term means "the cell that came first."

Prophase: phase in mitosis in which the centrosome divides and each half moves to the opposite end of the cell. Spindle fibers form and extend across the cell from centrosome to centrosome.

Prostate: muscular, glandular structure situated at the base of the male urethra which secretes an alkaline, thick fluid which is the major component of semen and which also functions as a valve controlling flow of urine or semen to the penis.

Prostomium: structure overhanging the mouth of worms; a type of lip.

Protein: three or more, usually complex, amino acids bonded together.

Protein Synthesis: process by which a cell makes protein. A message for the construction of a protein is sent from the DNA in the cell nucleus, via mRNA, to the ribosomes in the cytoplasm of the cell. A mRNA attaches to a ribosome, with help from rRNA. Next, amino acids are carried to this template via tRNA for the actual assembly of the new protein.

Protosome: form of embryological development characteristic of most invertebrates in which the mouth is formed from the lip of the blastophore stage, and the anus is formed secondarily, if at all.

Protozoa: phylum of unicellular, eukaryotic organisms.

Pseudocoelom: body cavity which lies between the gastrodermis and tissues of mesodermal origin.

Pseudopodia: "false feet." Projections of cytoplasm used for locomotion by members of the protozoan class *Sarcodina.* Pseudopodia also are found in a specialized form, such as in the white blood cells of man.

Pulmonary: relating to the lungs. The pulmonary trunk, which branches into two pulmonary arteries, carries venous blood from the heart to the lungs, and the pulmonary vein carries oxygenated blood from the lungs back to the heart.

Punnett Square: simple technique for calculating the probability of expected genetic cross results.

Pupil: contractile, usually round opening in the center of the eye's iris.

Purine: nitrogenous base which consists of a double ring of nine nitrogen and carbon atoms to which hydrogen, oxygen, and other nitrogen atoms are attached.

Pyloric Caeca: function in the secretion of digestive chemicals and also aid in the absorption of digested materials.

Pyloric Valve: valve which controls the flow of food from the stomach to the duodenum.

Pyrimidine: nitrogenous base which consists of a single six atom ring of carbon and nitrogen atoms to which hydrogen, oxygen, and other nitrogen atoms are attached.

Radial Symmetry: organization around a central point, like the spokes of a wheel, as exhibited by some sponges, coelenterates, and starfish.

Radula: horny band or ribbon in molluscs that bears minute teeth on its dorsal surface. It surrounds the tongue and tears up food to be drawn into the animal's mouth.

Rana pipiens: leopard frog.

Rectal Gland: gland connected to the rectum of sharks which serves to osmotically regulate body water content by the excretion of salt.

Renal Threshold: point at which the kidneys' ability to keep a chemical within the blood is exceeded, resulting in spill-over into the urine.

Resolving Power: on a microscope, how clear and sharp the magnified image of a specimen can be made.

Respiration: physical and chemical processes whereby a cell or organism supplies itself with metabolic energy. The by-products of aerobic respiration are carbon dioxide and water.

Retina: inner layer of the eye connected to the optic nerve which contains light-sensitive rods and cones which are the immediate instruments of vision.

Retting: controlled microbial decomposition of plant materials, so as to liberate certain components of the plant tissue. Used to produce linen fibers.

Rh Factor: any of one or more genetically determined substances present in the red blood cells of most persons and of higher animals, and capable of inducing antigenic reactions in those lacking the substance.

Ribonucleic Acid (RNA): nucleic acid, found in cells, which aids in the transfer of information within the cell. In some bacteria and viruses, it also functions like the DNA of eukaryotic cells, and in these special cases RNA is responsible for reproduction.

Ribose: five carbon sugar.

Rostrum: most anterior portion of a carapace; the exterior, dorsal covering of a crustacean.

Sagittal Crest: bony hump running along the suture lines of the skull which is formed in some primates and in *Australopithecus* and which holds massive jaw muscles required for chewing coarse food.

Salivary Amylase: enzyme found in saliva which promotes the break-down of starch into its component monosaccharide units.

Salivary Gland: gland which provides fluids and enzymes to the mouth and upper digestive tract.

Sarcodina: class of protozoa characterized by the use of pseudopodia for locomotion.

Sclera: dense, white fibrous outer layer of the eye which coats the eyeball, except for the front part covered by the cornea.

Scolex: head area, or knob-like structure armed with hooks or suckers by which tapeworms attach to a host, usually in the digestive tract. The scolex also contains the brain.

Scrotal Sac: external pouch in male mammals which contains the testes.

Semilunar Valve: valve which lies between the heart and the aorta and which consists of three flaps of tissue called cusps. It prevents the backflow of blood into the ventricles.

Semi-permeable Membrane: any membrane which allows some particles or molecules to pass through but not others. This permeability or lack thereof is often based upon molecular size.

Setae: surface bristles, used by the *Annelida* for locomotion.

Solute: dissolved substance.

Solvent: substance, usually liquid, capable of dissolving other substances.

Sperm: male gamete.

Spermatid: male gamete cell immediately after meiosis and before formation of a flagella.

Spermatogenesis: formation and maturation of sperm.

Spicule: internal skeletal structure of a sponge.

Spirillum: spiral-shaped bacterium.

Spleen: ductless vertebrate organ which lies near the stomach and which stores new and destroys old blood cells.

Spongin: protein material which composes the spicules of bath sponges.

Spongocoel: central internal cavity in a sponge.

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Sporozoa: class of parasitic protozoa characterized by a complex life cycle and the production of sexual spores.

Squalus acanthus: dogfish shark.

Staphylococcus: a genus of bacteria which grow in irregular clumps, members of which produce skin infections.

Stage: on a microscope, that which holds the specimen in position.

Statocyst: sensory organ for balance located on the foot of a mollusc.

Streptococcus: genus of bacteria which divide in one plane only and stick together to form long chains, members of which can cause sore throats.

Structural Formula: also known as Kekulé formula. A two-dimensional representation of a compound or molecule.

Sulcus: grooves in the ridges between convolutions, as in the surface of the brain.

Sus scrofa: pig.

Swimmeret: one of a series of small, unspecialized appendages under the abdomen of many crustaceans used for swimming or for carrying eggs.

Tapeworm: common name for parasitic flatworms in the class *Cestoda*, phylum *Platyhelminthes*. They are characterized by a scolex-type head and proglottid body.

Taxonomy: study of the classification of living organisms.

Telophase: final phase in mitosis in which the spindles disappear and chromosomes uncoil. Nuclear membranes also form, and the cytoplasm divides, creating two daughter cells.

Telson: seventh segment on the abdomen of crustaceans.

Thymine: pyrimidine base, one of the nitrogenous bases found only in DNA.

Trachea: also known as the windpipe. Part of the respiratory system in vertebrates, being a cartilaginous tube which connects the nose and mouth regions to the lungs. The trachea branches into smaller tubes, called bronchii, and they into yet smaller tubes before reaching the alveoli where gas exchange occurs.

Transfer RNA (tRNA): is thought to aid in the attachment of mRNA to ribosomes in the cytoplasm of the cell.

Trichina Worm: genus of unsegmented roundworms, class *Nematoda*, which cause trichinosis in man, an often fatal disease. The worms can be acquired by eating undercooked pork in which the trichina worms have encysted in the pig's muscles.

Tricuspid Valve: valve which lies between the right atrium and the right ventricle and which consists of three flaps of tissue called cusps. The tricuspid valve prevents backflow of blood.

Triglyceride: ester of glycerol which is bonded to one, two, or three fatty acids.

Tympanic Membrane: also called the eardrum. A thin membrane lying between the outer and middle ear which mechanically receives sound waves and transmits them to the inner ear.

Typhlosole: special type of intestinal tract in which there is an infolding of the intestinal wall, which greatly increases surface area for the digestion and absorption of food.

Umbo: hump, or oldest part of a mollusc shell.

Uracil: pyrimidine base, one of the nitrogenous bases found only in RNA.

Ureter: tubes leading from the kidneys to the urinary bladder.

Urinalysis: chemical analysis of urine, with deviations from normal indicating underlying pathology.

Urinary Bladder: sac-like structure which collects urine from the kidneys until excretion.

Urogenital Sinus: common opening of the urethra and vagina in some female mammals.

Uropod: either of the last, flattened lateral appendages on the seventh segment of crustaceans. The uropods lie on either side of the telson.

Uterine Tube: also known as oviduct or fallopian tube. In mammals, two tubes connect the ovaries to the uterus and provide passage for eggs.

Uterus: also known as the womb, a female organ for holding and nourishing the young until birth.

Vacuole: small cavity or space in a cell or an organism's tissues containing gas, fluid, or food. In protozoa, contractile vacuoles contain fluid or gas, and food vacuoles are used to digest food.

Vagina: canal in female mammals which leads from the uterus to the outside of the body and which is used for copulation.

Vein: any of the tubular branching vessels which carry blood from the capillaries back toward the heart.

Ventricle: chamber or chambers of the heart which receives blood from an atrium, and from which blood is pumped into the arteries.

Vertebrata: sub-phylum of the *Chordata* in which all animals possess a backbone.

Vestibule: area between the lips and teeth of an animal.

Villi: small, finger-like projections of the intestinal tract which absorb nutrients.

Vital Stain: stain which kills living cells slowly. May be used to clarify cell structures for viewing in temporary wet mounts while the cell still lives.

Vitreous Humor: gelatinous fluid which fills the area caudal to the lens in the eye.

Vomerine Teeth: teeth in the roof of a frog's mouth which emerge from its skull to hold prey.

Vulva: external genitalia of mammal females.

Wet Mount Slide: slide prepared for temporary use. Usually the specimen is placed upon a slide along with a drop of water and then covered with a coverslip.

Wolffian Duct: tube in frogs which functions like a ureter in higher vertebrates but which is structurally different from it. Wolffian ducts transport urine from the kidneys to the urinary bladder.

X-linkage: those traits of an organism determined by the X sex chromosome.

Appendix B:
Suppliers of Equipment, Materials, and Teaching Aids

The following partial list contains only those suppliers known to the author. However, since biological equipment, materials, and teaching aids are used heavily by the instructor, and since this usage requires advanced planning and early acquisition, a starting list was thought to be helpful. Listing of any supplier, or the opposite, does not represent endorsement, implied or otherwise. Other suppliers would be included in future editions, if their identities and product lines are brought to the attention of the author.

General Suppliers

Carolina Biological Supply (East Coast)
2700 York Road
Burlington, NC 27215
Toll Free: (800) 334-5551
(in North Carolina, (800) 632-1231)

Carolina Biological Supply (West Coast)
Powell Laboratories Division
Gladstone, OR 97027
Toll Free: (800) 547-1733

Connecticut Valley Biological Supply
P.O. Box 326, 82 Valley Road
Southampton, MA 01073
Toll Free: (800) 628-7748
(in Massachusetts, (800) 282-7757)

Delta Biologicals (East Coast)
P.O. Box 852
Vidalia, LA 71373
Toll Free: (800) 348-9587

Delta Biologicals (West Coast)
P.O. Box 26666
Tucson, AZ 85726
Toll Free: (800) 821-2502

Fisher Scientific
4901 W. LeMoyne Street
Chicago, IL 60651
(312) 378-7770

Frey Scientific
905 Hickory Lane
Mansfield, OH 44905
Toll Free: (800) 225-2629
(in Ohio, collect (419) 589-9905)

McKilligan Supply
435 Main Street
Johnson City, NY 13790
(607) 729-6511

Science Kit and Boreal Laboratories (East Coast)
777 East Park Drive
Tonawanda, NY 14150
Toll Free: (800) 828-7777
(in New York, collect (716) 874-6020)

Science Kit and Boreal Laboratories (West Coast)
P.O. Box 2726
Santa Fe Springs, CA 90670
(West Coast, collect (213) 944-6317)

Triarch
Dept. B — Box 98
Ripon, WI 54971
(414) 748-5125

Ward's Natural Science (East Coast)
5100 West Henrietta Road
P.O. Box 92912
Rochester, NY 14692
Toll Free: (800) 962-2660
(in New York, collect (716) 359-2502)

Ward's Natural Science (West Coast)
11850 East Florence Avenue
Santa Fe Springs, CA 90670
Toll Free: (800) 872-7289
(in Calif., collect (213) 946-2439)

Audiovisuals & Software

Many universities and government agencies hold extensive collections of films and videos available to the public at reasonable rates of rental. It is advisable to explore local availabilities before looking into the following outlets known to carry biological audiovisuals and software.

Audiovisuals Resources Section
Reference Services Division
National Library of Medicine
8600 Rockville Pike
Bethesda, MD 20209

Beckley Cardy
114 Gaither Drive
Mt. Laurel, NJ 08054
Toll Free: (800) 257-8338

Bio Learning Systems
Route 106
Jericho, NY 11753
(516) 433-2992

Cambridge Development Laboratory
110 Fifth Avenue, Dept. CT
Waltham, MA 02154
(617) 890-8076

Charles Clark Co.
168 Express Drive South
Brentwood, NY 11717
(516) 231-1220

Educational Images
P.O. Box 3456
Elmira, NY 14905
(607) 732-1090

Eye Gate Media
3333 Elston Avenue
Chicago, IL 60618
Toll Free: (800) 621-8086

Focus Media
839 Stewart Avenue
P.O. Box 865
Garden City, NJ 11530
Toll Free: (800) 645-8989

Human Relations Media
175 Tompkins Avenue
Pleasantville, NY 10570
Toll Free: (800) 431-2050
(in NY or Canada, (914) 769-7496)

Learning Arts
P.O. Box 179
Wichita, KA 67201
(316) 582-6594

Modern Talking Picture Service
5000 Park St North
St. Petersburg, FL 33709
(813) 541-5763

Prentice-Hall Media
ServCode DQ
150 White Plains Road
Tarrytown, NY 10591

Projected Learning Programs
P.O. Box 2002, Dept. D
Chico, CA 95927
(916) 893-4223

Rex Educational Resources
P.O. Box 2379
Burlington, NC 27216
(919) 229-4800

Schoolmaters Science
745 State Circle
P.O. Box 1941
Ann Arbor, MI 48106
Toll Free: (800) 521-2832
(in Michigan, (313) 761-5072)

Appendix C:

Answer Key

Part One: Getting Started

1. Discussion: Laboratory Equipment

Review: page 5

Matching

1. e
2. j
3. b
4. f
5. i
6. g
7. h
8. a
9. c
10. d

2. Discussion: Laboratory Safety

Discussion: pages 9 - 10

1. 2. 3. and 4. Answers will vary depending upon your school and available equipment.

5. It is important that both student and parent(s) or guardian(s) read and sign this statement.

Review: pages 13 - 14

Multiple choice

1. b
2. d
3. c
4. d
5. a
6. c
7. d
8. d
9. b
10. d

Short answer

Answers will vary.

3. Discussion: Science Vocabulary

Discussion: pages 17 - 18

1. a. Ab: away from. Ad: toward. Duct: the median length of the body, or tube. Abduct: to take away. Adduct: to bring toward.

   b. Homo: same. Hetero: different. Homogeneous: the same, or uniform. Heterogeneous: different, or varying.

   c. Geno: producing. Pheno: face. Genotype: that which produces characteristics, or types, as in cell genes. Phenotype: that which shows, or is the result of genes.

   d. Hyper: too much. Hypo: not enough. Hyperthyroidism: too much thyroxine. Hypothyroidism: not enough thyroxine.

   e. Bio: life. Eco: household. Zoo: animal. Ichthy: fish. Ornith: bird. Ology: the study of. Biology: the study of life. Ecology: study of the environment. Zoology: the study of animals. Ichthyology: the study of fish. Ornithology: the study of birds.

2. a. Endo: inside. Crine: from *krinein*, to separate. Endocrine: hormones secreted inside an organism's body by ductless glands.

   b. Herb: grass. Vore: devour. Herbivore: feeding on plants.

   c. Ortho: straight. Don: teeth. Orthodontist: one who straightens teeth.

   d. Endo: inside. Dermis: skin. Endodermis: the inner layer of skin.

   e. Ecto: outside. Therm: temperature. Ectothermic: cold-blooded.

   f. Gamete: single celled haploid reproductive cell. Phyte: plant. Gametophyte: the haploid reproductive cell of a plant.

   g. Com: with. Mensalis: at the table. Commensalism: living on or with another organism without harming or benefiting that organism.

   h. Meta: change. Morphosis: in form. Metamorphosis: changed in form.

   i. Myo: muscle. Card: heart. Myocardium: heart muscle.

   j. Pro: before. Zoa: animals. Protozoa: the simplest of all animals, unicellular animals.

3. a. Arthro: jointed. Poda: feet. *Arthropoda*: phylum of animals with jointed appendages.

   b. Asco: cup. Mycete: fungus. Aceae: plant class. *Ascomycetaceae*: class of cup fungi.

   c. Gymno: naked. Sperm: male gamete, or reproductive cell. Ae: plant subdivision. *Gymnospermae*: subdivision of naked seeded plants (not enclosed in an ovary).

   d. Nema: thread. Toda: phylum. *Nematoda*: phylum of thread worms.

   e. Ortho: straight. Ptera: wing. *Orthoptera*: insect order with two pairs of straight wings, or none, if there is an incomplete metamorphosis.

Review: page 19

Matching

1. o
2. f
3. g
4. e
5. l
6. n
7. m
8. b
9. c
10. d
11. a
12. j
13. h
14. i
15. k

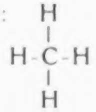
Part Two: The Cell

4. Exercise: Chemical Models

Exercise: pages 23 - 30

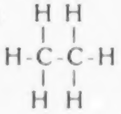
1. See puzzle. There are actually thirty elements to be found in the scramble, and two others which cannot be counted because of incorrect spellings. Answers will vary as to which elements students see first.

2. Methane:



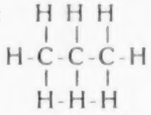
$$\begin{array}{ccc} & H & \\ & | & \\ H- & C & -H \\ & | & \\ & H & \end{array}$$

Ethane:



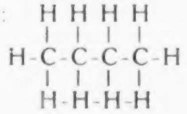
$$\begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H- & C & - & C & -H \\ & | & & | & \\ & H & & H & \end{array}$$

Propane:



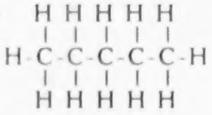
$$\begin{array}{ccccccc} & H & & H & & H & \\ & | & & | & & | & \\ H- & C & - & C & - & C & -H \\ & | & & | & & | & \\ & H & - & H & - & H & \end{array}$$

Butane:



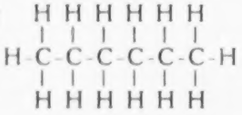
$$\begin{array}{ccccccccc} & H & & H & & H & & H & \\ & | & & | & & | & & | & \\ H- & C & - & C & - & C & - & C & -H \\ & | & & | & & | & & | & \\ & H & - & H & - & H & - & H & \end{array}$$

Pentane:



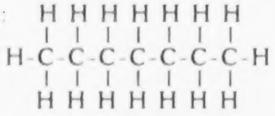
$$\begin{array}{ccccccccccc} & H & & H & & H & & H & & H & \\ & | & & | & & | & & | & & | & \\ H- & C & - & C & - & C & - & C & - & C & -H \\ & | & & | & & | & & | & & | & \\ & H & & H & & H & & H & & H & \end{array}$$

Hexane:



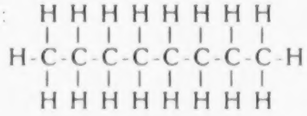
$$\begin{array}{ccccccccccccc} & H & & H & & H & & H & & H & & H & \\ & | & & | & & | & & | & & | & & | & \\ H- & C & - & C & - & C & - & C & - & C & - & C & -H \\ & | & & | & & | & & | & & | & & | & \\ & H & & H & & H & & H & & H & & H & \end{array}$$

Heptane:



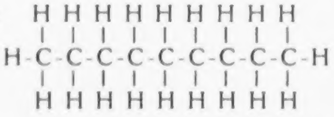
$$\begin{array}{ccccccccccccccc} & H & & H & & H & & H & & H & & H & & H & \\ & | & & | & & | & & | & & | & & | & & | & \\ H- & C & - & C & - & C & - & C & - & C & - & C & - & C & -H \\ & | & & | & & | & & | & & | & & | & & | & \\ & H & & H & & H & & H & & H & & H & & H & \end{array}$$

Octane:



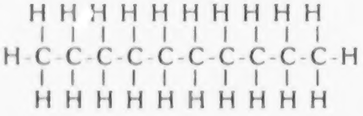
$$\begin{array}{ccccccccccccccccc} & H & & H & & H & & H & & H & & H & & H & & H & \\ & | & & | & & | & & | & & | & & | & & | & & | & \\ H- & C & - & C & - & C & - & C & - & C & - & C & - & C & - & C & -H \\ & | & & | & & | & & | & & | & & | & & | & & | & \\ & H & & H & & H & & H & & H & & H & & H & & H & \end{array}$$

Nonane:



$$\begin{array}{ccccccccccccccccccc} & H & & H & & H & & H & & H & & H & & H & & H & & H & \\ & | & & | & & | & & | & & | & & | & & | & & | & & | & \\ H- & C & - & C & - & C & - & C & - & C & - & C & - & C & - & C & - & C & -H \\ & | & & | & & | & & | & & | & & | & & | & & | & & | & \\ & H & & H & & H & & H & & H & & H & & H & & H & & H & \end{array}$$

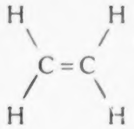
Decane:



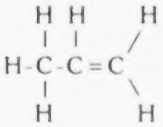
$$\begin{array}{ccccccccccccccccccccc} & H & & H & & H & & H & & H & & H & & H & & H & & H & & H & \\ & | & & | & & | & & | & & | & & | & & | & & | & & | & & | & \\ H- & C & - & C & - & C & - & C & - & C & - & C & - & C & - & C & - & C & - & C & -H \\ & | & & | & & | & & | & & | & & | & & | & & | & & | & & | & \\ & H & & H & & H & & H & & H & & H & & H & & H & & H & & H & \end{array}$$

3. Methane cannot become methene, because methane does not have two carbon atoms with which to form a double bond.

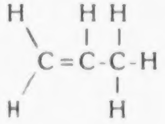
Ethene:



Propene:



Note that the mirror image of propene is:

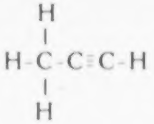


Both equations for propene are correct. The remaining alkenes possess one double bond in any one of the carbon bonds.

4. Again, methane cannot become methyne, because methane does not have two carbon atoms with which to form a triple bond.

Ethyne: $\mathrm{H-C\equiv C-H}$

Propyne:

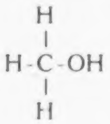


$$\begin{array}{ccccc} & H & & & \\ & | & & & \\ H- & C & - & C\equiv C & -H \\ & | & & & \\ & H & & & \end{array}$$

Both this equation and its mirror image for propyne are correct. The remaining alkynes posses one triple bond in any one of the carbon bonds.

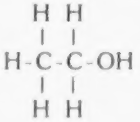
5. Answers will vary.

6. Methyl alcohol:



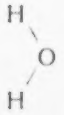
$$\begin{array}{ccc} & H & \\ & | & \\ H- & C & -OH \\ & | & \\ & H & \end{array}$$

Ethyl alcohol:

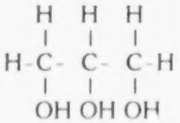


$$\begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H- & C & - & C & -OH \\ & | & & | & \\ & H & & H & \end{array}$$

Water:

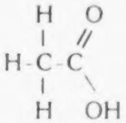


Glycerol:

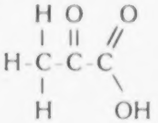


$$\begin{array}{ccccccc} & H & & H & & H & \\ & | & & | & & | & \\ H- & C & - & C & - & C & -H \\ & | & & | & & | & \\ & OH & & OH & & OH & \end{array}$$

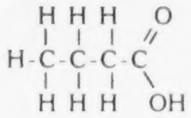
Acetic acid:



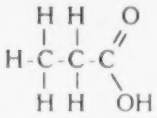
Pyruvic acid:



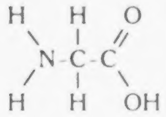
Butyric acid:



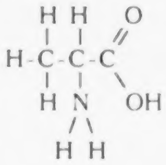
Carboxylic acid:



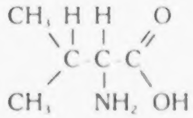
7. Glycine:



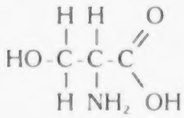
Alanine:



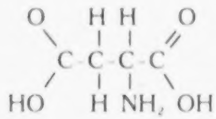
Valine:



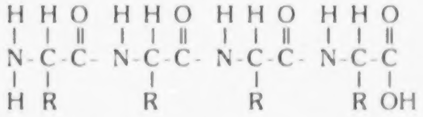
Serine:



Aspartic acid:



8.



The product is a tripeptide, or protein.

Review: pages 31 - 32

Matching

1. c
2. a
3. b
4. a
5. a, b, & c
6. a, b, & c
7. a
8. c
9. a
10. b

Fill in the blanks

11. carbohydrate
12. sucrose
13. side by side
14. oils or waxes
15. alcohol, or aldehyde
16. acid
17. peptide

Matching

18. m
19. l
20. k
21. f
22. i
23. g
24. j
25. b
26. a
27. d
28. n
29. h
30. c

5. Laboratory: Organic Compounds

Laboratory: pages 35 - 38

1. Sugar crystals liquify and, as heating continues, begin to turn brown. When all liquid has been driven off, the remaining solid material turns black. This is a standard test for carbon.

2. Caramel.

3. $C_{12}H_{22}O_{11} \xrightarrow{\Delta + \text{air}} C + H_2O$ vapor. The water is driven off as vapor. This equation is not balanced.

4. The sulfuric acid reacts with the sugar to form a heat of reaction sufficient to hydrolize the sugar into carbon and water.

5. $C_{12}H_{22}O_{11} + H_2SO_4 \longrightarrow C + H_2O$ vapor $+ SO_2$ fumes. This equation is not balanced.

6,7,8,9,10,& 11. Answers will vary.

12. Benedict's solution tests for the presence of monosaccharides and reducing sugars. Sucrose, or table sugar, is a disaccharide, and it will test negative with Benedict's solution.

13. Answers will vary.

14. Green is a partially positive test for sugar. Perhaps you are testing a disaccharide which has partially decomposed into monosaccharide units.

15. Deep purple indicates the presence of considerable protein; baby blue is a partially positive test for protein.

Review: page 39

Short answer

1. Carbon turns black from the heat of reaction.

2. Benedict's solution, when treated, turns from blue to brick red in color in the presence of sugar.

3. Iodine turns from brown-red to blue-black in the presence of starch.

4. Ninhydrin, when heated, turns from clear in color to lavender in the presence of protein.

5. Brown paper and Sudan III solution are two different tests for the presence of fats and oils. Brown paper will become translucent, and remain that way even when dried, when a fat or oil is rubbed onto it. Sudan III is soluble in oils, and it will diffuse into oil droplets and turn the droplets pink. If oil is present in a solution, a pink "ring" will form in a layer in a test tube.

6. Photosynthesis, and by feeding on other organisms. Energy is stored within cells in the high energy bonds of ATP, or adenosine tri-phosphate.

6. Laboratory: Acids, Bases, and Buffers

Laboratory: pages 43 - 47

1,2,& 3. Observation.

4. The solution is acidic.

5. The solution is basic.

6. pH paper. pH paper indicates the amount of basicity/acidity, whereas litmus paper simply indicates if a substance is acidic or basic.

7,8,9,10,11,12,13,14,15,16,17,& 18. Observation.

19. More like the buffer, sodium phosphate. Because liver is an organic tissue, which contains many natural buffers.

20 & 21. Enzymatic reactions are specific and only accomplished within rigid guidelines of temperature, pressure, and pH. Living tissues must maintain this homeostasis in order to survive. Therefore, tissues contain many natural buffers in order to guard against untoward changes in pH.

Review: pages 49 - 50

Multiple choice

1. a
2. c
3. d
4. a
5. a
6. d
7. b
8. d
9. a
10. c

Essay: good answers should include the following:

a. Sodium phosphate is an inorganic buffer.

b. Buffers monitor the pH in a system so that neutrality is maintained. They accomplish this by combining with either an excess of hydrogen ions or hydroxide ions, depending on which ion is in excess.

c. Living tissues contain buffers, because many proteins, such as enzymes, can operate only within a narrow range of temperature and pH.

d. The buffers in living systems function similarly to all buffers, like sodium phosphate.

7. Laboratory: Spit

Laboratory: pages 53 - 55

1. Yes. Iodine turns blue-black in the presence of starch. There is indeed starch in test tube #1.
2. No. Benedict's solution turns orange in the presence of simple sugars. There is no sugar in test tube #2.
3. Controls.
4. Answers will vary depending upon the nature and contents of the saliva (how much salivary amylase present, as opposed to mucus). There should have been a reaction in test tube #3 in which the iodine turned blue-black, demonstrating the presence of starch.
5. Yes. There should have been at least a partially positive test indicating the presence of sugars in test tube #4.
6. Yes. Iodine turns blue-black in the presence of starch. There is indeed starch in test tube #5.
7. No. Benedict's solution turns orange in the presence of simple sugars. There is no sugar in test tube #6.
8. Salivary amylase must aid in the hydrolysis, or digestion, of starch into its component monosaccharide units.
9. Test tube #3 contained saliva. Test tube #1 did not. Every experiment must have a control test in order to provide valid results.
10. Salivary amylase must have been degraded upon heating. This explains why there are no sugars present in test tube #6.
11. Observation.

Review: page 57

Essays: good answers should include the following:

1. a. Enzymes are organic catalysts, and as such affect the rate of a reaction without themselves being consumed by the reaction.

   b. Enzymes operate within rigid confines of temperature, pressure, and pH.

   c. Enzymes are specific to a chemical reaction and the compounds upon which they act.

2. a. Enzymes are protein compounds as defined in essay #1.

   b. When an enzyme must combine with another compound in order to be effective, it is called an apoenzyme.

   c. A coenzyme is a non-protein component which is required by an enzyme for enzymatic action to occur. Coenzymes may be simple metal ions, such as copper or iron, or they may be highly complex substances not easily isolated or identified.

3. Salivary amylase is a naturally occurring enzyme in saliva which causes the breakdown of starch. Therefore, digestion, both mechanical and chemical, begins as soon as food is placed in the mouth.

8. Laboratory: The Microscope

Laboratory: pages 61 - 66

1. The high power objective gives greater magnification. It is used for close detail work, while the low power objective is used for scanning.

2,3,4,& 5. Answers will vary depending upon the type of microscope used.

6. Answers will vary.

7. The student focuses on different parts of the fibers and obtains a three dimensional view.

8 & 9. Both lighting and the ability to focus sharply are reduced as magnification is increased. The same amount of light that illuminates low power must suffice for high power objective observations.

10 & 11. Answers will vary.

12. The area is decreased.
13. Observation.
14. Upside down and backwards.
15. It appears to move to the left.
16. It appears to move toward you.
17. It is the lens through which you view the specimen.
18. Holds the slide in position.

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19. Regulates the amount of light.

20. Magnification.

21. Bring the specimen into focus.

22. Provides light with which to view the specimen.

23,24,25,26,27,28,& 29. Based on observations.

Review: pages 69 - 70

Identification

1. eyepiece
2. adjustment knob
3. arm
4. base
5. light source
6. diaphragm
7. stage
8. stage clip
9. objective
10. revolving nosepiece

Short answer

11. One on the arm and one under the base.

12. Lens paper, or cheesecloth.

13. Stage clips.

14. Toward you.

15. It is decreased.

16. 60X.

17. How sharply or well it can bring a specimen into focus.

18. Diaphragm.

19. Low power objective at the lowest level.

20. Answers will vary, but should include sturdiness, magnification, resolving power, light source, and focusing ability.

9. Laboratory: Cells

Laboratory: pages 72 - 80

1. Observation.

2. Yes. These cells are all bark cells from the cork tree. They inherited their shape and size, which is determined by the shape of their cell wall.

3 & 4. No. These cells are dead and as such have no contents. Bark cells are for protection and contain only cell walls once they mature.

5 & 6. Observation.

7. Yes. Onion cells are plants and as plants have cell walls. The cell walls determine the shape of the cell.

8. It kills them.

9. Iodine brings into clarity cell structures and shape, although it does kill the cell.

10. No.

11. Yes. As you focus up and down on a cell, you will see different cellular levels.

12. No.

13. No. The onion epidermal cells are found in the onion bulb, a food storage container for the onion. These cells are not exposed to sunlight, and therefore they do not photosynthesize.

14. Cork cells are dead with no cellular contents. Onion cells are living, with both cytoplasm and a nucleus visible through a light microscope.

15 & 16. Observation.

17. Basically similar. There will be some variation, depending upon the amount of starch storage in the leucoplasts of the individual cell, but they all play the same role and share the same general design.

18. Turns them blue-black.

19. Although iodine brings cell structures and shape into clarity, it kills them.

20. No. Again, these are specialized food storage cells for the potato, and they do not photosynthesize.

21. Yes. Because the leucoplasts turn blue-black in the presence of iodine. This is the standard test for starch.

22. Answers will vary depending upon what position the leaf occupies on the wet mount slide.

23. Yes.

24. Clockwise.

25. Yes.

26. No.

27. Chloroplasts are the organelles in plants which contain chlorophyll. Chlorophyll is the green pigment that photosynthesizes, thereby obtaining from the sun the energy needed for life. *Elodea* leaf cells demonstrate a phenomena only a few plants have developed, that of cytoplasmic streaming. The cytoplasm moves in a single direction around the large interior vacuole and near the cell wall. The chloroplasts in the cytoplasm therefore move in the same direction. Each chloroplast is exposed to the maximum sunlight available to the leaf. Maximum photosynthetic efficiency is thus achieved. The light source in the microscope stimulates this cytoplasmic reaction, similar to the rays of the sun.

28 & 29. Observation.

30. The outer edge of a cheek cell consists of a cell membrane; the outer edge of an *Elodea* cell is a cell wall.

31. Answers will vary, but all should describe a roundish shape. They should all be of similar, but not the same, shape.

32. Answers will vary; however, cheek cells have cell membranes and nuclei visible through the light microscope. *Elodea* cells have cell walls, nuclei, a central vacuole, and chloroplasts visible through the light microscope.

33. To bring out the shape of the nucleus and also to demonstrate the presence of cytoplasm within the cell membrane.

34. No. Cheek cells do not photosynthesize.

35. Observation.

36. Blood cells are more structured. Both outer edges are cell membranes.

37. Answers will vary. However, all red blood cells are the same shape, and a doughnut with a thin area instead of a hole would be a good description. Red blood cells are highly specialized cells, and their shape is mechanically the best for taking in and discharging gases, such as oxygen and carbon dioxide. If students see leucoplasts, or white blood cells, they will be amoeba-like, and variable in form.

38. In their shape.

39. Answers will vary, depending upon prior life science courses.

40. Methylene blue would not show with red blood cells. Also, methylene blue differentially stains nuclei, and there are no nuclei in mature red blood cells. Therefore, it would be pointless to stain red blood cells with methylene blue.

Review: pages 81 - 82

Multiple choice

1. d	4. d	7. c	10. b	13. d
2. d	5. c	8. b	11. d	14. c
3. a	6. b	9. b	12. b	15. a

10. Laboratory: Cell Membrane Diffusion

Laboratory: pages 85 - 86

1. To clean off any excess starch or sugar solution. They would invalidate your results.
2. Sugar.
3. Clear or pale blue.
4. Orange-red. If the student only obtained marginal results, the color would still change to green.
5. That the glucose solution inside the dialysis tubing moved through the tubing membrane and into the water in the beaker.
6. None.
7. It would indicate that the starch suspension had moved through the dialysis tubing membrane into the water in the beaker.
8. Glucose consists of six carbon atoms with attached hydrogen and oxygen atoms. Starch is thousands of carbon atoms in length. As both glucose and starch contain the same kinds of atoms, but with a great difference in amounts, perhaps you might assume that diffusion across the semi-permeable tubing membrane is based on molecular size.
9. The fact that sugar molecules passed through the membrane, but starch molecules did not.
10. Yes. Dialysis.

Review: page 87

Matching

1. d	3. h	5. c	7. i	9. a
2. e	4. j	6. b	8. f	10. g

11. Station Laboratory: Food and Respiration

Laboratory: pages 91 - 95

1. Sugar.
2. To keep the by-product of respiration, carbon dioxide, in the bottle.
3. Fermentation time varies because environmental conditions, such as temperature, vary. Also, in homemade root beer, the exact amount and viability of the yeast used will vary from batch to batch.
4. Answers will vary. Injection of bottled gas and the use of dry ice (frozen CO_2) are common answers.
5. Alcohol.
6. Sugar.
7. Answers will vary. However, all answers should indicate that lactic acid bacteria can withstand quantities of salt, whereas other bacteria generally do not. Also these bacteria create an acidic environment which inhibits the growth of other organisms, thus preserving the food. Other types of food preservation include the use of large amounts of salt, vinegar, or sugar, as well as freezing, canning, and drying.
8. There are other flavor changes as well. The bacteria eat the sugar in the cabbage. This not only changes the flavor, but also the consistency of the cabbage.
9. Answers will vary, but pickles, sauerkraut, corned beef, buttermilk, and cheeses are examples.
10. Swiss cheese.
11. Answers will vary.
12. Crumpets, or, some might say, English muffins.
13. The gluten in the dough. Students might merely note the flour.
14. Sugar.
15. No. The yeast uses the sugar in the flour mixtures, and in doing so changes the taste and consistency of the product.
16. Yes. See question #15.
17. $CH\text{-}COOH + 2O_2 \longrightarrow 2CO_2 + 2H_2O$.
18. Because environmental conditions, such as room temperature, will vary, because the amount of acetic acid bacteria initially introduced into the liquid will vary depending upon location, and because the initial success of the yeast in creating an environment conducive to the rapid growth of acetic acid bacteria will vary, depending upon the viability of the yeast used and the amount of oxygen exposed to the liquid.

19. Sugar.

20. By breaking the sugar into intermediate products, such as alcohol, for use by the acetic acid bacteria.

21. Discussion answers will vary, but the problem is the food poisoning called botulism.

22. Rot, slime, or other appropriately descriptive words.

23. Salt, sugar, or vinegar.

24. Aerobe: with oxygen. Anaerobe: without oxygen. Facultative anaerobe: with or without oxygen.

25. Aerobe: acetic acid bacteria. Anaerobes: lactic bacteria and butyric acid bacteria. Facultative anaerobe: yeast.

26. Respiration: the energy-yielding process of living organisms. It requires oxygen. Fermentation is also an energy-yielding process, but it takes place in the absence of oxygen.

27 & 28. Answers will vary.

29. Explanations will vary depending upon the student's familiarity with sourdough breads.

Review: page 97

Multiple choice

1. d 3. a 5. c 7. c 9. a
2. c 4. b 6. a 8. b 10. a

12. Laboratory: Leaf Pigment Separation

Laboratory: pages 100 - 102

1 & 2. Answers will vary depending upon the brand of felt marker used.

3. The answer should be yes, because materials and conditions for the experiment were identical. If the student answers negatively, there should be an explanation of some material or condition which was not identical in the experiment.

4. Answers will vary depending upon the brand of felt tip marker used.

5. The component compounds which were mixed to make the ink.

6. Felt tip marker ink is water soluble, chlorophyll is not.

7. Two.

8. Yes. See answer to question #3.

9. No. The dots on the two filter paper strips should be the same in position and color. One dot on each strip should be a clear green color, while the other should be yellowish green in color.

10. The two compounds which together constitute spinach leaf chlorophyll. These are called chlorophyll *a* and chlorophyll *b*.

11. They are mixed, and the eye sees the overall color.

12. Answers will vary, but students may approach it in terms of either light duration, light intensity, or temperature changes. A typical answer will note the disappearance of chlorophyll with autumnal cooling and the resulting visibility of pigments, which previously had been masked.

13. Answers will vary.

Review: page 103

Essay: good answers will include the following:

1. a. Solution to be tested is placed upon filter paper.
   b. Solvent is brought into contact with the filter paper and works its way up the paper by capillary action.
   c. The solution being tested is carried along by the solvent, its individual compounds being re-deposited upon the paper differentially according to their solubility in the solvent.
   d. Paper chromatographic separation is a simple way of physically separating solutions into their component compounds.
2. a. Chlorophyll is the photosynthetic agent in plants. Other pigments exist which aid in photosynthesis, such as the carotenoids and phycobilins, but they cannot photosynthesize without chlorophyll.
   b. Chlorophyll is located in chloroplasts in eukaryotic plants.
   c. There are seven different types of chlorophyll known, chlorophylls *a*, *b*, *c*, *d*, and *e*, bacteriochlorophyll, and bacterioviridin. Plants contain the chlorophylls which function best for the environment in which they grow. Most eukaryotic plants contain a mixture of chlorophylls *a* and *b*.

13. Exercise: DNA Models

Exercise: pages 107 - 108

1. DNA has a ladder-like structure which is twisted into a spiral. This could also be described as a double helix.

2. Five carbon deoxyribose sugar molecules alternating with a phosphate group.

3. The nucleotide. It is composed of a deoxyribose sugar, a phosphate group, and a nitrogenous base.

4. Adenine and guanine.

5. Cytosine and thymine.

6. Uracil.

7. Adenine always bonds with thymine, and guanine always bonds with cytosine. In RNA, uracil takes the place of thymine.

8. mRNA originates in the nucleus of the cell. A strand of DNA duplicates a section of itself which contains the message to be transmitted to the cell. This single-stranded section of DNA is mRNA, and it is small enough to travel through the nuclear membrane into the cytoplasm of the cell, where it attaches itself to a ribosome in order to serve as a template for protein synthesis.

9. tRNA is found in the cytoplasm of the cell. It carries protein molecules to mRNA molecules attached to a ribosome in the sequence needed for protein synthesis.

10. Ribosomes provide the structure upon which different mRNA templates attach. Ribosomes also channel the energy with which protein synthesis is accomplished.

11. rRNA is called ribosomal RNA, and it is thought to help in the transfer of protein molecules from tRNA to the mRNA template upon the ribosome.

12. DNA is a double stranded helix, while RNA is a single stranded helix. DNA contains thymine, while RNA contains uracil. DNA contains deoxyribose, while RNA contains ribose.

Review: pages 109 - 110

Matching

1. c	3. j	5. e	7. i	9. g
2. a	4. d	6. f	8. b	10. h

Essay: good answers should include the following:

1. a. DNA is shaped like a ladder of many rungs which has been twisted into a spiral.
   b. The sides of this ladder are composed of alternating units of a five carbon deoxyribose sugar and a phosphate group. The rungs are composed of nitrogenous bases.
   c. Every sugar and phosphate group with an attached nitrogenous base is called a nucleotide, and the nucleotide is the basic unit of structure for a DNA molecule.
   d. The bases are the purines, adenine and guanine, and the pyrimidines, cytosine and thymine. Besides bonding to the ladder's side, adenine bonds only to thymine, and cytosine only to guanine.
2. DNA molecules contain messages that direct how a cell functions and reproduces. These messages are sent to the cytoplasm of the cell via mRNA molecules. mRNA molecules attach themselves to ribosomes with the aid of rRNA molecules, and tRNA molecules bring protein molecules to the mRNA-ribosomal complex. The protein molecules are synthesized, or put together, on the mRNA-ribosomal complex with the aid of rRNA.

14. Exercise: Phases of Mitosis and Meiosis

Exercise: pages 115 - 121

1. Interphase, prophase, metaphase, anaphase, telophase.
2. Observation.
3. Cellular respiration, growth, and repair.
4. The spindle provides the framework upon which the chromosomes divide evenly.
5. The formation of a cellulose cell wall in plants is initiated in the center of the mother cell, and spreads outward, dividing the mother cell into two daughter cells by cytokinesis. This formation is called a division plate.
6. Prophase precedes metaphase, and metaphase begins as paired chromatids gather along the equator.
7. Observation.
8. Chromosomes, cells.
9. Chromatids.
10. Nuclear membrane.
11. Interphase, prophase, metaphase, anaphase, and telophase.
12. For the exact replication of genetic material, which is necessary for the continuity and stability of the organism.
13. Puzzle. See answers to #14.
14. a. DNA
    b. Spermatogenesis
    c. meiosis
    d. haploid
    e. oogenesis
    f. thymine
    g. mitosis
    h. anaphase
    i. replication
    j. homologue
    k. RNA
    l. aster
    m. spindle
    n. genes
    o. gamete
    p. metaphase
    q. adenine
    r. interphase
    s. tetrad
    t. prophase
    u. centromere
    v. diploid
    w. polar body
    x. synapsis
    y. purine
    z. chromosomes
    aa. Watson
    bb. cytosine
    cc. sperm
    dd. centrosome
    ee. cell plate, furrow
    ff. helix
    gg. telophase

Review: pages 123 - 124

Multiple choice

1. c	5. c	9. d	13. c	17. c
2. a	6. c	10. d	14. c	18. b
3. d	7. d	11. d	15. d	19. b
4. c	8. b	12. a	16. d	20. c

15. Exercise: Gene Mutations

Exercise: pages 127 - 130

1. U-G-C-A-A-C-A-U-C-G-U-G-G-U-C-U
2. Cysteine - asparagine - isoleucine -valine - valine
3. G-C-A-A-C-A-U-C-G-U-G-G-U-C-U
4. Alanine - threonine - serine - tryptophan - serine
5. It is now used.
6. Yes. All of the resulting amino acids are different.
7. Less effect. The amino acid cysteine would no longer be coded, but the remaining amino acids would be the same as on the original strand. This is far less of a mutation than having all the amino acids different from those on the original strand.
8. One, or as many as two.
9. A change in one base pair: GAA to GUA, or GCG to GUG. A change in two base pairs: GAA to GUU, GUC, or GUG, or GCG to GUU, GUC, or GUA.

10. Mutations are unlikely events in the first place; it is less probable that two mutations would occur simultaneously.

Review: pages 131 - 132

Matching

1. e
2. i
3. g
4. c
5. d
6. a
7. b
8. j
9. h
10. f

Essay: good answers should include the following:

1. Protein functions should be given in specific terms, and cover the following categories:
   a. Dynamic functions: transportation, metabolic control, chemical transformations.
   b. Structural functions: bone and connective tissue matrix and body shape.
2. Mutations can occur:
   a. Naturally, for no reason presently known. Some DNA replications are more at risk for this than others.
   b. Through exposure to materials in the environment, such as irradiation and exposure to cancer causing carcinogens.

Part Three: The Flow of Life

16. Exercise: Genetics, Probability, and Punnett Squares

Exercise: pages 137 - 144

1. RR, Rr, Rr, and rr.

2. 1:2:1.

3. 3:1.

4. Whatever the number of offspring, they would still maintain the same ratio. For 24 this would be 6 RR, 12 Rr, and 6 rr.

5,6,7,& 8. Observation.

9. Yes. Because the more observations you make, the closer will be your results to the results predicted by probability.

10. Observation.

11. YYLL, YYLl, YyLL, YyLl; YYLl, YYll, YyLl, Yyll; YyLL, YyLl, yyLL, yyLl; YyLl, Yyll, yyLl, yyll.

12. 1:1:2:2:4:2:2:1:1.

13. 9:3:3:1.

14. Double the genotypic and phenotypic numbers given in questions #12 and #13.

15,16,17,& 18. Observation.

19. Yes. Because the more observations you make, the closer your results will be to the results predicted by probability.

20. Observation.

21. All four of them.

22. Law of dominance.

23. Law of segregation.

24. They are different genotypically, in that heterozygotes look like the dominant trait but carry the gene for the recessive trait.

25. The appearance of these genotypic results are in a 1:2:1 ratio; see question #1 for a visual explanation of this ratio. Both homozygous and heterozygous dominant will appear as the dominant trait, and only the homozygous recessive animal will show the recessive trait. Therefore, the genotypic ratio becomes a 3:1 phenotypic ratio.

26. 3:1.

27. The law of independent assortment states that a characteristic governed by a particular gene is not influenced by other genes.

28. The hybridizer should know which trait will predominate when he makes a cross. Otherwise, his results are not predictable.

29. 7, because Mendel experimented with seven independent traits.

Review: pages 145 - 146

Matching

1. e
2. c
3. i
4. h
5. d
6. a
7. g
8. b
9. f
10. j

Diagram

11 & 12. All Bb.

13. Black.

14. Bb.

15 & 16. BB, Bb, Bb, bb.

17. 3 black, 1 white.

18. BB, Bb, and bb.

19. 1:2:1.

Short answer

20. Gregor Mendel.

21. Probability.

22. Answers will vary.

23. Dihybrid cross.

24. The results that should occur are not necessarily those that do.

25. Round and yellow.

17. Exercise. Monohybrid and Dihybrid Crosses

Exercise: pages 147 - 157

1. If "A" represents axial flowers, and "a" represents terminal flowers, then Aa is crossed with aa. The offspring will have the genotypes Aa and aa in a 1:1 ratio. Aa will have axial flowers, and aa will have terminal flowers.
2. If "I" represents inflated-seed pods and "i" represents constricted-seed pods, then Ii is crossed with ii. The offspring will have the genotypes Ii and ii in a 1:1 ratio. Ii will have inflated-seed pods, and ii will have constricted-seed pods.
3. If "Y" represents yellow-seeded plants and "y" represents green-seeded plants, YY is crossed with yy to produce 100% Yy yellow-seeded plants.
4. If "S" represents short hair and "s" represents long hair, parents SS and ss will produce 100% Ss short-haired offspring. If these offspring are self-crossed, 1 will be SS short-haired, 2 will be Ss short-haired, and 1 will be ss long-haired.
5. If the two brown mice are heterozygous for the trait, Bb and Bb, then every 3 of their offspring will show the dominant trait, while 1 will show the recessive trait, white. This can be shown in a Punnett square.
6. If "G" represents green and "g" represents yellow, the genotypes must be Gg and gg.
7. Heterozygous monohybrid crosses show a 3:1 phenotypic ratio. If there were 48 brown otters, then there should be 16 cream-colored otters.
8. F_1 generation Pp. 16 green elephants and 48 pink.
9. Bb and bb.
10. 174 starchy.
11. 63 white squash.
12. 50%.
13. 50 should have the formula "C" amd 50 the formula "c." None should have the formula Cc because eggs are haploid gametes.
14. 6, because that is one-fourth of 24, and the offspring of a heterozygous cross is always phenotypically in a 3:1 ratio.
15. Bb and Bb.
16. 25%, because the parents are both heterozygous for the trait.
17. Ll and Ll.
18. All the children have the genotype Cc, which means that they all will have cataracts.
19. Rabbits. They breed much faster.
20. Hh; the bull is hornless.
21. a. RY
    b. RrYy
22. a. Ry, Ry, rY, and ry.
    b. RY, Ry, rY, and ry.
    c. 1:2:2:1.
    d. 9.
23. a. Ai, AI, Ai, and aI.
    b. Ai, AI, aI, and ai.
    c. 1:1:1:1.
    d. 4.
24. a. TC, Tc, tC, and tc.
    b. TC, Tc, tC, and tc.
    c. 1:1:1:1.
    d. 4.
25. a. gi and gl.
    b. gi and gl.
    c. 1:1.
    d. 2.

26 & 27. The student should show in a Punnett square that there are nine different genotypes with four different phenotypes possible.

28. BBss X bbss. Offspring will be Bbss, or black, long-bodied bees.
29. 9 will have square heads and green eyes, 3 will have square heads and purple eyes, 3 will have round heads and green eyes, and 1 will have a round head with purple eyes.
30. According to the story, Rudolph's father could fly, and both parents had black noses. If "B" represents black noses and "b" red, while "W" represents walking and "w" flying, then Rudolph's parents were BbWw and Bbww. Students should show in a Punnett square all possible offspring from such a cross.
31. a. Rr X rr.
    b. Rr X Rr.
32. a. Rrbb
    b. RrBb
    c. RRBB.
33. His Leghorn chickens were not pure, or homozygous Leghorns. Students should demonstrate this in a Punnett square.
34. a. 1 in 4.
    b. 1 in 4.
    c. 1 in 4.
    d. 3 in 4.
    e. 3 in 4.
35. Observation. The Punnett square should be 8-sided with a total of 64 cells.

Review: pages 159 - 161

1. Gg and brown.
2. Bb and bb.
3. Bb.

4. 48.

5. 10.

6. 16 pink and 48 orange.

7. 50%.

8. 16.

9. 3 in 16.

10. TtWw.

18. Exercise: Incomplete Dominance, Sex-linked Inheritance, and Nondisjunction

Exercise: pages 163 - 171

1. a. 1:1.
   b. 25%.

2. 1 TTrr (tall, red flowered).
   3 TTrw (tall, pink).
   2 Ttrr (tall, red).
   3 Ttrw (tall, pink).
   1 TTww (tall, white).
   2 Ttww (tall, white).
   1 ttrr (short, red).
   2 ttrw (short, pink).
   1 ttww (short, white).

3. a. 1/16th.
   b. 0.
   c. 1/8th.

4. The farmer's Andalusian blues are a case of incomplete dominance, in that the cross between black and white produces 100% blues. If he self-crosses the blues, he will always get a mixture of colored offspring. He must cross pure black with pure white chickens in order to get 100% blue offspring.

5. Blue with white, or bw X ww gives 50% blue, 50% white. Similar results are obtained blue with black, or bw X bb.

6. 0.

7. 50%.

8. 1 in 4.

9. X^gX and X^gY.

10. The boy, because he received his X chromosome from the mother. The girl might have received the same chromosome from the mother, but it would be masked by the normal X chromosome which she received from her father.

11. Half of the girls and also half the boys would be color-blind, or two of each sex.

12. 0.

13. 1 in 4, a boy.

14. 0.

15. 75%.

16. X^hX.

17. Both parents are normal for hemophilia, but have the genotype XY and X^hX.

18. X^hX and X^hY.

19. 100%.

20. In any cell.

21. Turner's syndrome is XO, a case where the 23rd chromosome pair did not receive half of its genetic load.

22. Nondisjunction of the egg - superfemales and Klinefelter's syndrome.

    Nondisjunction of the sperm - XYY males.

    Nondisjunction of either the egg or the sperm - Turner's syndrome.

23. Nondisjunction of autosomes - Down's syndrome.

24. Nondisjunction of the sex chromosomes - see question #22.

Review: pages 173 - 174

Matching

1. h
2. e
3. b
4. i
5. c
6. d
7. j
8. a
9. f
10. g

Problems

11. Incomplete dominance.

12. 6 red, 12 pink, 6 white.

13. 1 in 4.

14. XY and X^hX.

15. Answers will vary.

19. Laboratory: Blood Typing

Laboratory: pages 177 - 178

1,2,3,& 4. Answers will vary.

Review: pages 179 - 180

Multiple choice

1. a & c
2. c
3. d
4. b & d
5. b,c,& d
6. b
7. b
8. d
9. b
10. b

20. Exercise: Pedigree Studies and Human Genetic Traits

Exercise: pages 182 - 190

1 & 2. Answers will vary.

3 & 4. Observation.

5,6,7,8,9,& 10. Answers will vary.

Review: pages 191 - 192

Solve the problems

1 & 2. Observation.

3. Observation and discussion. Their offspring would all carry the trait for cystic fibrosis, but none would suffer from the disorder. Half their offspring would possess and show the trait for brachydactyly, but brachydactyly merely means that the individual will be unusually short in comparison to a normal population. As a genetic counselor they should be informed of this fact, but also reassured that there is no other adverse effect from brachydactyly.

21. Laboratory: Natural Selection

Laboratory: pages 196 - 199

1,2,3,4,5,6,7,8,9,& 10. Answers will vary.

11. The reduction in foraging time symbolizes the effectiveness of the predators in relation to each other. Those less successful during the first generation will not reproduce as successfully.

12. Either the spoon or the fork will be most effective, because of a shape suitable for foraging on the type of prey available and the texture of the carpet.

13. One of the legumes, because of shape, color, and the carpet (the natural environment), will be taken less frequently as predators rush to maximize their take.

14. Probably the knife (or chopsticks when used by the non-adept), because of poor adaptation to the test at hand.

15. Reasons for lack of survivability will be the same as in question thirteen.

16. The first generation. During the first generation of foraging all predators were able to forage for the same amount of time. Hence, their success or lack of it will be demonstrated all the more obviously.

17. Answers will vary, but there is an obvious interplay between predators, prey, and the environment.

18. Extinction. Eventually their numbers will become so decimated by lack of success in foraging, or lack of success in evasion, that they will cease to exist.

Review: page 201

Essay: good answers should include the following:

1. a. Evidence for evolution.
    1). Embryology
    2). Comparative anatomy
    3). Systematics
    4). Geographical distribution

   b. Causes of evolution: competition
    1). Competition and selection cause change.
    2). Overpopulation enhances competition.
    3). There is competition between males for breeding opportunities.
    4). Fertility and susceptibility to disease are mechanisms of evolution.

   c. Causes of evolution: use and disuse
    1). The inheritance of acquired characteristics.

2. a. Natural Selection
    1). An ongoing evolutionary process in which members of a species whose modifications suit their environment survive, and those whose modifications place them at a disadvantage die off.
    2). Those organisms which survive are those with the most and best adaptive traits. These include the ability to compete successfully for food, water, shelter, and other essential possessions, the ability to reproduce and perpetuate the species, and the ability to resist adverse natural forces, which are the agents of selection.

   b. Survival of the fittest means that only the best adapted live. It is an essential aspect of the theory of natural selection.
    1). Because resources are limited, individuals, both within the same species and between species, must struggle for a share of food and space.
    2). The struggle for the survival of the fittest is perpetual, because the natural environment constantly changes, and only the fittest of the competitors survive.

   c. Answers will vary.

22. Exercise: Fossil Boy

Exercise: pages 206 - 208

1,2,& 3. *Homo habilis* skull area 3,300 mm., brain area 1,590 mm., and ratio 2.1:1; *Homo erectus* skull area 4,400 mm., brain area 1,963 mm., and ratio 2.2:1; and, *Homo sapiens* skull area 4,020 mm., brain 2,376 mm., and ratio 1.7:1.

4. Answers will vary, but all should include the idea that brain area has increased in humans over time.

5. *Homo sapiens*. *Homo habilis*. See the answer to question four. Also, the face area has shrunk relatively as brain area has increased.

6. Answers will vary, but possibilities include teeth (shape and wear patterns indicate diet), pelvic bones (which reveal posture), fossils of other species and datable minerals in the same deposit (which reveal geologic age and potential food), tools associated with the fossil (level of technical skill), etc.

7. Answers will vary, but all should include a definition of neoteny.

8. Answers will vary, but possibilities include the connection between neoteny and increased total gestational periods. In other words, as an organism takes longer and longer to mature, expanding the length of time in which it is dependent upon its parents, it may eventually mature while still maintaining some of the characteristics of its juvenile ancestors. A complex correlation between maturity, morphology, and total gestational periods may exist. As a corollary to this, the brain may continue to grow long past a set stage of maturity in the ancestors.

Review: page 209

Matching

1. e
2. d
3. b
4. f
5. c
6. a
7. c
8. g
9. h
10. i

Essay: good answers should include the following:

a. Changes in structure, such as skull size and shape, teeth, pelvis, and total size.

b. Changes in culture, such as tool use, fire, speech, and a ritual life.

23. Laboratory: Soil Communities

Laboratory: pages 214 - 220

1,2,3,& 4. Answers will vary.

5. The environment is different in leaf litter and in topsoil. Usually leaf litter will be drier, warmer, and with more available oxygen than topsoil.

6. Answers will vary depending upon the soil, climate, and types of organisms found in your locality.

7,8,9,& 10. Answers will vary.

Review: pages 221 - 222

Multiple choice

1. d
2. c
3. d
4. a
5. d
6. d
7. a
8. d
9. c
10. c

24. Class Laboratory: Bacterial Populations

Laboratory: pages 226 - 228

1,2,3,4,& 5. Observation.

6. The incubator.

7,8,9,10,11,12,13,14,& 15. Observation.

16. Answers will vary. However, they should note the spread of diseases through the four basic mediums of air, water, food, and contact.

Review: page 231

Fill in the blanks

1. cell wall
2. bacillus
3. fission
4. *Streptococcus*, or infection
5. pathogen
6. cell walls
7. air, water, food, or contact
8. epidemic
9. Robert Koch
10. agar

25. Exercise: Classification

Exercise: pages 233 - 239

1. **Sequentially:** 1) *Nymphalidae*, 2) *Syrphidae*, 3) *Corydalidae*, 4) *Tipuloidea*, 5) *Saturnidae*, 6) *Tabanidae*, 7) *Aegeriidae*, 8) *Chrysopidae*, 9) *Saturnidae*, 10) *Ploiariidae*, 11) *Dytiscidae*, 12) *Simuliidae*, 13) *Cicadae*, 14) *Blattariae*, 15) *Belostomatidae*, 16) *Ephemeridae*, 17) and *Phthiriidae*.

2 & 3. Answers will vary.

4. Yes, it is possible. Answers will vary depending upon the initial structures used when answering question three.

5. Answers will vary, but possibilities include length, height, weight, window types and angles, grill design, use of chrome, engine size and type, interior and exterior colors, etc.

6. A dichotomous key forces you to consider all differences and similarities between objects, not just the few noticed at a glance. Also, you are forced to determine which of the differences and similarities are more fundamental, and which more superficial.

Review: page 241

Answers will vary.

Part Four: Invertebrates

26. Laboratory: Protozoa

Laboratory: pages 248 - 251

1. Answers will vary, but adjectives might include the following: slow, flowing, lumbering. Also, students might describe the protoplasm flowing within the pseudopodia.

2. Descriptions will vary. Material passing in to an amoeba is food.

3. Answers will vary, but the growth and expulsion of a contractile vacuole can be likened to blowing bubbles. Growth can be measured, and the expulsion occurs very rapidly.

4 & 5. Observation.

6. Students should observe a muscular gliding motion, flagellar movement, and an inching movement.

7. Anterior.

8. No.

9. *Euglena*, being an autotroph, swims toward light.

10. For food getting. The *Euglena*, in adverse situations, can become heterotrophic in order to survive.

11. *Euglena* is plant-like in that it contains chloroplasts and can photosynthesize. It is animal-like in that it can be heterotrophic, feeding with its gullet and reservoir, and is free swimming.

12. Answers will vary; however, adjectives such as smooth and fast might be used.

13. Not particularly.

14. Answers will vary.

15. Observation.

16. Shape: *Amoeba* varies, *Plasmodium* is basically round, *Euglena* can change its shape but is basically oval with pointed ends, and *Paramecium* is shaped like a slipper.

    Speed: *Amoeba* is very slow, *Plasmodium* does not move, *Euglena* can move rapidly, and *Paramecium* is very fast.

    Feeding and digestion: *Amoeba* engulfs its food in pseudopodia, *Plasmodium* is parasitic in blood cells, *Euglena* photosynthesizes but can feed in certain situations, and *Paramecium* is a hunter, particularly of bacteria.

17. Terms such as taxonomy, kingdom, phylum, class, family, genus, species, binomial nomenclature, sexual, asexual, spore, conjugation, binary fission, oral groove, pseudopod, vacuole, mutualism, locomotion, DNA, RNA, parasite, *Plasmodium*, heterotroph, *Amoeba*, *Euglena*, *Paramecium*, *Protista*, *Volvox*, *Sarcodina*, *Mastigophora*, and *Ciliata*.

Review: pages 253 - 254

Multiple choice

1. a
2. a
3. b
4. c
5. a
6. a
7. a
8. c
9. c
10. a
11. a
12. c
13. d
14. d
15. b
16. c
17. c
18. d
19. c
20. d

27. Laboratory: Sponges

Laboratory: pages 258 - 260

1. The pores, or ostia and oscula.

2. Water goes in through the ostia, and out through the oscula.

3. Yes.

4. Students, now that they have cross-sectioned their specimen, should be able to see canals radiating from the ostia, called incurrent canals, which attach to radial canals which are connected to the spongocoel. From the spongocoel water is propelled out the oscula.

5. Choanocyte flagellation draws water into and through the sponge. The choanocytes capture and digest food brought into the sponge with the water.

6. From the water. Some food is digested by the choanocytes, but most is passed on by the choanocytes to amoebocytes in the mesoglea, where the amoebocytes digest and pass nutrients to all parts of the sponge body.

7. Cellular specialization: choanocytes, amoebocytes, and the production of spicules and mesoglea for support and structure.

8 & 9. Observation.

10. Calcium carbonate.

11. Observation.

12. Asexual reproductive structures composed of clumps of cells surrounded by a protective covering.

Review: page 261

Fill in the blanks

1. *Porifera*, 2. bearing many pores or holes, 3. salt, 4. sessile, 5. radial, 6. pores or holes, 7 & 8. epidermis and endodermis, 9. mesoglea, 10. osculum, 11. spongocoel, 12. spicules, 13,14 & 15. calcium carbonate, silicon, protein (spongin), 16. spicules, 17. spongin (protein), 18 & 19. debris and microorganisms, 20. water, 21. ostia, 22. choanocytes, 23. choanocytes, 24. amoebocytes, 25. oxygen, 26. ostia, 27. amoebocytes, 28. wastes, 29. osculum, 30. asexually, 31,32,& 33. regeneration, budding, & gemmules, 34. sexually, 35. internal.

28. Laboratory: Hydra

Laboratory: pages 266 - 268

1. Five.

2. Answers will vary, but the animal should be in a rounded or balled up position if disturbed or threatened.

3. It elongates, or stretches out.

4. Answers will vary. Some students will observe only movement of the body (elongation) and waving of the tentacles. Some students may describe the gliding movement of the basal disc as the animal rearranges its position on the watch glass.

5 & 6. It protectively reforms a ball.

7. Yes. The entire body of the animal reacts to distance itself from the probe. There is more than a simple tissue response in the direct area of contact.

8. The animal tries to avoid the light.

9. There is no reaction to blue light.

10. One or more tentacles make contact with the water flea, with the other tentacles following. The flea stops struggling after stinging, and the *Hydra* draws it toward its mouth.

11. Something immobilizes the flea so that it stops struggling.

12. See question ten. Add the following description: the *Hydra* draws the flea into its stomach cavity, and extracellular enzymes begin to dissolve it.

13. Yes. Explanations of how the *Hydra* coordinates its movements will vary, but should include mention of the nerve net.

14. The *Hydra* actively captures and subdues live prey, while the sponge filters debris from the water.

15. Observation.

Review: page 271

Multiple choice

1. d
2. c
3. d
4. d
5. a

True or false

6. F
7. T
8. F
9. F
10. T
11. F
12. T
13. F
14. T
15. T

29. Laboratory: Planaria

Laboratory: pages 276 - 278

1. Answers will vary, depending on the individual organism and the species.

2 & 3. Answers will vary.

4. Students will probably observe a gliding movement, although some may describe the alternate pattern of planarian movement, which is like an inchworm.

5. Braces against it, and points its auricle end against the current.

6. Answers will vary, but the student probably will consider the reaction to a water current as a defensive posture designed to keep from being swept downstream.

7. Withdraws from the touch.

8. Withdraws from the touch, but not as strongly as when touched in the head region.

9. The animal withdraws.

10. There will either be no reaction at all, or the planaria will withdraw from the light, but not as strongly as when the light is shone on the head region.

11. The planaria will go toward the liver and wrap itself around it or on it, depending upon the size of the liver. Its proboscis then will be extruded into the liver.

12. The animal withdraws.

13. Observation.

Review: pages 279 - 280

Multiple choice

1. a
2. d
3. b
4. c
5. a
6. c
7. c
8. d
9. a
10. d

Essay: good answers should include the following:

1. *Turbellaria:* free-living flatworms.

   Trematoda: parasitic flukes which attach to the host by means of suckers. Mostly ectoparasites, but some are endoparasites, such as bilharzia.

   Cestoda: parasitic tapeworms, largely endoparasites which have lost their mouths and digestive tracts but which have structures for clasping such as a scolex, and segmented proglottids for reproduction.

2. Answers will vary greatly, as this is a thought question. However, students might consider a wide range of organ systems, such as those possible in humans. Also, students might discuss the different environmental niches that can be exploited by specialized organisms.

30. Laboratory: Ascaris

Laboratory: pages 284 - 286

1,2,& 3. Observation.

4. No. Respiration is accomplished by simple diffusion directly through the epidermal and cuticle layers of the worm. Circulation also is accomplished by simple diffusion of fluids within the worm's body.

5. Answers will vary, but all should include the following: as with all parasites, reproduction involves the huge production of eggs, because only a few will succeed in infecting another host. The cuticle is highly resistant to digestion. The life cycle of the worm matches the structures of the host to maximize reinfection. Locomotion, a skeleton, and sense organs such as eyes are not important.

6. Summary.

Review: pages 289 - 290

Multiple choice

1. d
2. b
3. c
4. b
5. d
6. b
7. c
8. b
9. a
10. c

True or false

11. T
12. T
13. T
14. F
15. T
16. F
17. T
18. F
19. T
20. T

31. Laboratory: Earthworms

Laboratory: pages 293 - 298

1. Dorsal

2. Answers will vary; however, since soil is darker and the sky lighter, the earthworm will more nearly blend into the soil, if looked at from above, because of the darker dorsal side. If looked at from below, it will more nearly blend into the skyline because of the lighter ventral side.

3,4,5,6,&7. Answers will vary.

8. On the lateral sides of the segments.

9. There are two pairs on every segment, except for the first three and the last segment.

10. They push the animal, and by their position keep the animal from sliding backwards.

11. Seven. Segments 30-36.

12. The animal thins and lengthens.

13. The animal fattens and shrinks in length.

14. Mouth - 1; buccal cavity - 1; pharynx - 2-6; esophagus - 7-14; crop - 15-17; gizzard - 18-20; intestine -21-end; anus - last segment.

15. Yes, the original number of these segments is always the same, the first twenty of which contain the vital organs. The worm grows by adding segments to the intestine holding part of the body.

16. Answers will vary.

17. Earthworms lime his fields.

18. Observation.

19. Increased surface area in contact with food means an increase in the absorption of food per a given length of intestine.

20. All earthworms have both male and female sex organs. This is the definition of a hermaphrodite.

21. Observation.

22. Five. Segments 7-11.

23. Blood is circulated through blood vessels to all parts of the body. It does not bathe the body cavity in general.

24. Five hearts - dorsal blood vessel - ventral blood vessel, repeating.

25. One pair.

26. To all parts of the worm's body.

27. Segments three and four.

28. By simple diffusion through the skin. This is why the skin of an earthworm must remain moist. If it dries out, the worm can no longer breathe.

Review: pages 299 - 300

Practical: questions 1 - 10. The instructor will pin dissected earthworms with numbered pins, and the student must then identify the organs thus pinned.

Matching

11. f
12. h
13. g
14. b
15. i
16. j
17. a
18. e
19. d
20. c

Multiple choice

21. c
22. d
23. a
24. b
25. c
26. c
27. d
28. a
29. c
30. a

32. Laboratory: Clams

Laboratory: pages 304 - 306

1. All have shells constructed of two valves, or two parts.

2. Answers will vary, but it will be dark.

3 & 4. Answers will vary depending upon the clam species being dissected.

5. An irritant, such as a grain of sand, gets between the mantle and the valve. The clam deposits nacre around the particle to protect itself.

6. To the valves. Yes, to open and close the valves.

7,8,& 9. Observation.

10. Food enters with water through the incurrent siphon. The organic debris sticks to the mucous on the gills. Mucous continually empties into the mouth, and the mucous containing debris is swallowed and sent to the stomach. Digestion takes place in the typhlosole intestine, waste products collect in the rectum, and they are eventually excreted through the anus and excurrent siphon.

11. The shell, foot, and radula. Also, the organ systems of some of the molluscs are far more sophisticated than anything studied up to this point.

Review: pages 309 - 310

Multiple choice

1. b
2. c
3. d
4. d
5. a
6. a
7. b
8. c
9. c
10. b

Order the following intestinal sequence correctly

11. d
12. k
13. j
14. e
15. a
16. f
17. b
18. c
19. g
20. h

33. Laboratory: Starfish

Laboratory: pages 313 - 316

1. Answers will vary.

2. Radial.

3. Observation.

4. Five.

5. Observation.

6. Mouth, esophagus, cardiac stomach, pyloric stomach, intestine, rectal sac, anus.

7. The nerve ring encircles the mouth, and five radial nerves feed to the arms from this ring. Externally there are five eyespots, one on the tip of each arm, which respond generally to changes in light. Also, the tentacles and tube feet exhibit sensitivity to touch.

8. Observation.

9. Water enters the system via the madreporite plate and travels along the canals. The muscles of the ampullae of the tube feet expand or contract, causing the ampullae to expand or contract, which causes the water in the tube feet to create, via hydrostatic pressure, suction or its release, depending upon the amount of water in the tube feet from the canals, which are valved.

10. Summary.

Review: pages 319 - 320

Multiple choice

1. d
2. a
3. b
4. c
5. d
6. c
7. b
8. a
9. d
10. b
11. a
12. b
13. c
14. d
15. a

34. Laboratory: Crayfish

Laboratory: pages 324 - 325

1,2,3,4,& 5. Observation.

Review: pages 327 - 328

Multiple choice

1. c
2. a
3. b
4. a
5. b
6. b
7. b
8. c
9. b
10. d

Identification

11. f
12. b
13. j
14. e
15. a
16. i
17. h
18. g
19. d
20. c

Part Five: Vertebrates

35: Laboratory: Sharks

Laboratory: pages 332 - 334

1. Answers will vary.
2. Five.
3. Observation.
4. Usually the student will identify four rows of teeth emerging from the inside dermal area of the jaws. The uppermost row of teeth is slanted backwards into the mouth region, but completely free of the jaw. The other rows will be partially to completely parallel to the jaw line.
5. The shark, for the duration of its life, always will be able to eat. This is unlike most mammals, who die of starvatio when their teeth wear out.
6. They both arise from the dermis, they are made of the same material (enamel), and they are shaped similarly. However, they are used for different purposes.
7. No. Shark teeth do not arise from a bony jaw, and they are continually being replaced, unlike mammal teeth.
8. Answers will vary.
9. Greatly increased surface area for the absorption of nutrients, and a structure which ensures the continual movement of material through the intestine.
10. Answers will vary, but they should include references to shark teeth and the shark's spiral valve intestine.

Review: pages 335 - 336

Multiple choice

1. a
2. d
3. d
4. c
5. d
6. b
7. a
8. c
9. c
10. d
11. a
12. d
13. a
14. c
15. d

36. Laboratory: Perch

Laboratory: pages 339 - 341

1. Observation.

2 & 3. Answers will vary.

4. From the bony endoskeleton.
5. Different. Shark's teeth appear to arise from the dermis, unlike perch. Also, shark's teeth are continually replaced by new teeth as they wear out, as well as made of cartilage. Perch teeth cannot be replaced and are composed of bone.
6. Into the esophagus and also the gill chambers.
7. No. Fish nostrils have a blind end.
8. Respiration.
9. To hold internal organs and structures in place in the coelom.
10. Three.
11. Answers will vary.
12. Primarily as a hydrostatic organ, but also as a back-up respiratory reserve.
13. Spawning is conditioned by the time of year. During spawning season the gonads will be larger.
14. Yes. By the size of the gonads.

Review: pages 343 - 344

Multiple choice

1. d
2. c
3. c
4. d
5. c
6. b
7. b
8. d
9. b
10. c
11. e
12. a
13. d
14. b
15. c

37. Laboratory: Frogs

Laboratory: pages 346 - 352

1. It is attached to the front of the buccal cavity.
2. It helps the frog to catch and hang on to prey.
3. Frogs swallow their food whole and need the wide space.
4. To the inner ears and tympanic membranes.

5. To the mouth.
6. Being on top of the body, the frog's eyes and nostrils can still function in air while the rest of the body is submerged.
7. To hold prey in the mouth.
8. Lower.
9. To the heart.
10. Answers will vary, but all students should suggest that because the striations are parallel to the appendages, they function in moving the limbs.
11. Three.
12. To make and store bile.
13. Answers will vary.
14. To hold the organs and structures of the coelom in place.
15. Answers will vary, depending upon the frog's condition and from what part of the intestine the section was taken.
16. Observation.
17. Answers will vary.
18. They function like the ureters of higher vertebrates, in the transport of urine from the kidneys to a urogenital opening, or cloaca in the case of the frog.
19. Summary.

Review: pages 355 - 356

Multiple choice

1. a	5. b	9. c	13. b	17. c
2. d	6. c	10. c	14. c	18. d
3. c	7. d	11. c	15. d	19. c
4. a	8. c	12. c	16. d	20. d

38. Laboratory: Pigs

Laboratory: pages 360 - 363

1,2,3,4,& 5. Observation.

Review: pages 365 - 366

Identify the following

1. l	4. o	7. n	10. h	13. m
2. k	5. b	8. e	11. d	14. j
3. a	6. i	9. f	12. c	15. g

Essay: good answers should include the following:

1. a. Behavioral: care for the young and the ability to learn.
   b. Structural: limb position, diaphragm, and teeth.
   c. Physiological: temperature control and activity levels.
2. Reproduction: egg-laying and incubation in the monotremes, initial egg nourishment and placental attachment, followed by development in the pouch, in marsupials, and true placenta which both nourish and attach the fetus to the uterus in placental mammals.

39. Laboratory: The Digestive System

Laboratory: pages 371 - 373

1. Instructor's signature.
2. Pigs are mammals whose young develop within the uterus of the mother attached to her bloodstream by a placenta. Fetal nutrition, as well as waste disposal, is accomplished by an exchange of nutrients between the bloodstream of the mother and the fetus via the umbilical cord. The stomach, like the lungs, is not used until parturition when the animal becomes air breathing.
3. Villi are small, finger-like projections of tissue which absorb nutrients in the upper small intestine, or duodenum.
4. It regulates the flow of materials from the small to the large intestine.
5. Four.
6. Observation.
7. The liver produces bile which is stored in the gall bladder until used in digestion in the stomach. The liver also alters substances in the blood, such as converting glucose into glycogen (which is then stored in the liver until required by the body).
8. The pancreas is a large gland of vertebrates which secretes many of the enzymes of digestion, as well as the hormone insulin.

Review: pages 375 - 376

Multiple choice and sequencing

1. d	5. d	9. b	13. a	17. j
2. c	6. a	10. d	14. f	18. c
3. d	7. c	11. i	15. b	19. g
4. d	8. b	12. h	16. d	20. e

40. Exercise: Calories and You

Exercise: pages 380 - 382

1,2,3,4,5,6,7,8,9,10,11,12,13,14,& 15. Observation. Answers will vary.

Review: pages 385 - 386

Short answer: good answers should include the following:

1. A category of food. Food often is grouped by the nutrient, vitamin, or mineral it supplies. Basic food groups used in this manual are milk (and milk products), vegetables, fruits, protein/meats, and starch/breads.
2. One Calorie, the unit used by nutritionists, equals one kilocalorie, or 1,000 calories. A calorie is the amount of energy required to heat one gram of water one degree centigrade.
3. Food density is the Caloric content of food per unit weight. Nutritionists use this to manipulate diets of those with appetite or weight problems. For example, the condition of underweight people with small appetites would be helped by high density foods and overweight people with large appetites by low density foods.

4. Fiber content, vitamin content, and mineral content of foods. Also, adequate water intake.

5. Natural: those foods cooked directly from an unrefined form. Processed: those foods which have been manipulated for purposes of storage, taste, or appearance. For example, dehydrated potatoes, canned or frozen orange juice (some with sugar added), and dried milk. Imitation: those foods which have been chemically manipulated to resemble natural foods. For example, mutton processed to appear and taste like ham, or seaweed or moss extract replacing the eggs traditionally used to thicken ice cream.

6. Answers will vary.

41. Laboratory: Circulatory and Respiratory Systems

Laboratory: pages 388 - 395

1. Signature.

2. The atria are thin-walled sacs at the cranial end of the heart; the ventricles are heavy-walled sacs at the caudal end of the heart.

3. The head and forelegs.

4. Veins. Pulmonary veins from the lungs, and the cranial and caudal venae cavae.

5. To shunt blood between the pulmonary trunk and the aorta, so that blood will not flow into the lungs in the fetal animal.

6. After the baby is born, the ductus arteriosus changes into a functionless solid cord called the arterial ligament.

7. The spleen is responsible for the storage of new and the disposal of old red blood cells, as well as the manufacture of lymphocytes.

8. Renals: service the kidneys.

   Iliacs: service the anal/tail region of the animal.

   Median sacral: also service the anal/tail region of the animal.

   Umbilical: serve as connector vessels through the placenta to the mother. Nutrients and oxygen are provided through the umbilical vessels, and the wastes of the fetal animal also are disposed of through these vessels.

   Hepatic: serves the liver.

9. Vena Cava: the major vein entering the heart. The cranial vena cava enters from the head region of the animal.

   Jugulars: service the head region of the animal.

   Subclavians: service the two forelimbs of the animal.

   Mammaries: service the nipple and chest area of the animal.

   Hemiazygous: the azygos veins serve as a supplementary channel between the cranial and caudal vena cavae, and the hemiazygous vein branches downward toward the kidney on the left side of the vertebral column of the animal cord.

10. Aorta: major artery leaving the heart.

    Coeliac: this artery branches off the aorta ventral to the kidneys to service the coelom of the animal.

    Mesenterics: these arteries branch off the abdominal aorta ventral to the kidneys and service the mesentery of the abdominal cavity.

    Renals: service the kidneys.

    Lumbars: paired arteries arising from the aorta which supply the muscles of the dorsal abdominal wall. They branch from the aorta near the caudal end of the kidneys.

    Iliacs: branches of the abdominal arteries. The external iliacs feed into the hindlegs, and the internal iliacs service the pelvic region of the body.

    Median sacral: service the anal/tail area from the caudal end of the abdominal aorta.

    Umbilical: this artery travels from the abdominal aorta to the umbilical cord.

11. Brachiocephalic: emerges off the aortic arch and branches into the brachial, carotids, and other arteries cranial to the heart.

    Carotids: paired arteries emerging from the brachiocephalic and servicing the animal's head region.

    Subclavians: paired arteries emerging from the brachiocephalic and servicing the animal's head region, traveling toward the ears.

    Costocervical: branches from the dorsal surface of the subclavian at the level of the first rib. This occurs close to the brachiocephalic artery. The costocervical services the brain.

    Mammaries: emerge from the subclavians and pass caudally in the thoracic wall near the midventral line of the pig. These are usually difficult to identify during a dissection because they are often destroyed when the chest cavity is first opened.

    Subscapulars: branches of the axillary arteries which service the forelimbs.

    Thyrocervicals: emerge from the subclavian just cranial to the origin of the internal mammary. They service the muscles of the chest and back.

12. Arteries have thicker, muscular walls. Veins have thinner walls, and simple valves to prevent the backflow of blood.

13. Semilunar: a valve with three cusps located between the left ventricle and the aorta. The semilunar valve prevents backflow of blood from the aorta into the left ventricle.

Bicuspid: a valve with two cusps located between the left atrium and the left ventricle. It prevents backflow of blood from the ventricle into the atrium.

Tricuspid: a valve of three cusps located between the right atrium and the right ventricle. It prevents backflow of blood from the ventricle into the atrium.

14 & 15. Observation.

16. Support. It would be disastrous if the trachea were in danger of collapse.

17. The diaphragm acts as a billows, or pump, to force air in and out of the lungs.

18. No. The lungs of fetal pigs have not been used for breathing and have not been expanded to their full potential volume.

19. They blow up like a balloon, unless there is a hole in them from the dissection.

20. The alveoli in the lungs have been filled with air.

Review: pages 397 - 398

Multiple choice and identification

1. b
2. b
3. a
4. a
5. b
6. a
7. d
8. b
9. a
10. b
11. b
12. a
13. f
14. g
15. i
16. h
17. c
18. e
19. d
20. j

42. Exercise: Your Pulse Rate

Exercise: pages 400 - 403

1,2,3,4,& 5. Observation.

6. Answers will vary. **UNLESS** there is a difference in the amount of cardiovascular fitness, due to differences in exercise levels between the two groups, the return of boys and girls to normal pulse rate should be the same.

7 & 8. Answers will vary.

9. Answers will vary; however, most students will cite emotional states, such as excitement, or illness.

10 & 11. Observation.

12. Answers will vary, and conclusions will vary. Normally, holding the breath tends to slow down heartbeat, but some students will actually record an increase in heartbeat (pulse rate) with the face under water because of fear.

Review: pages 405 - 406

Essay: good answers should include the following:

1. a. Transport by the bloodstream.

   b. Oxygen collected by the lungs.

   c. Gas wastes excreted by the lungs.

   d. Other metabolic wastes transported to the kidneys and removed by excretion.

2. a. Increase in activity levels of the cells under stress.

   b. Cells increasing metabolism to fuel increased activity levels.

   c. Bloodstream increasing delivery of oxygen and nutrients to the cells, along with increased metabolic rates and requirements for waste removal.

   d. Heart increasing its beat rate in order to pump more blood to the cells, thus increasing delivery of oxygen and nutrients.

3. Answers will vary, but students obviously should comment on improvements to cardiovascular fitness which should result from regular exercise.

43. Laboratory: Excretory and Reproductive Systems

Laboratory: pages 409 - 413

1. Signature.

2. Observation.

3. Excess water is removed by the kidneys, and the proper balance of ions and chemicals is maintained by filtration of the blood.

4. It blows up like a balloon, but it can become still larger. The muscles of the urinary bladder are smooth, or involuntary muscles. They slowly stretch in response to steady pressure.

5 & 6. Observation.

7. Urinary bladder, ureters, urethra, umbilical veins, arteries, and cord are all similar. Also, students might comment that the reproductive structures are modifications with a common origin.

8. Ovaries/testes, vagina, penis and structures, prostate gland, bulbourethral gland, urogenital sinus, genital tubercle, uterus and structures, oviduct, seminal vesicle, and the ductus deferens.

9. Answers will vary; however, all students should state that the pig can produce large litters of animals versus the one child (or two) typical of humans. The disadvantage is that there are many piglets for the sow to tend, with litter fatalities sometimes rather high.

10. They are physically integrated.

Review: page 415

List in order

1. d
2. c
3. b
4. f
5. e
6. a
7. c
8. b
9. e
10. d
11. a
12. c
13. a
14. d
15. b

44. Laboratory: Urinalysis

Laboratory: pages 418 - 420

1,2,3,& 4. Observation.

5. Yes, unless the student did the experiment incorrectly.

6. Observation.

7. Yes, unless the student did the experiment incorrectly.

8. Observation.

9. Fasting.

10. Yes, unless the student did the experiment incorrectly.

11. Observation.

12. Heavy exercise or emotional upset.

Review: page 423

Short answer

1. Slightly acidic, slightly yellowish, slightly aromatic, and a specific gravity slightly greater than water.

2. Albuminuria is an abnormal condition in which albumin, a protein, is found in urine. The Heller ring test, in which concentrated nitric acid is added to a urine sample, identifies albuminuria. Albumin is one of the three primary blood fractions; if it is found in the blood, it is because the permeability of the kidneys' capillaries has abnormally changed.

3. Acetone is a ketone protein, and it is identified by the Lange test in which glacial acetic acid and saturated sodium nitroprusside are added to a urine sample, after which ammonium hydroxide is added. Acetone is present in the urine if the body oxidizes fat instead of glucose. It is one sign of diabetes.

4. Sugar in urine is one indication of diabetes. The sample urine is heated with Benedict's solution, and if the mix turns color, the test is positive. Glycosuria is the name given to this disorder. Sugar is found in urine if there is so much in the bloodstream that the renal threshold of the kidneys is exceeded, and it spills over into the urine.

45. Laboratory: The Sense Organs

Laboratory: pages 426 - 431

1. The nictitating membrane protects the eyes from damage and yet also allows the animal to see, albeit not as clearly if the membrane were not in place. Animals that spend time underwater, such as ducks, and those that burrow and root in soil, such as pigs, often have nictitating membranes.

2. Observation.

3. The lens magnifies the print. As the position of the lens is changed relative to the print, the magnification changes.

4. Answers will vary but should include the ideas of a sound funnel and protection.

5. Answers will vary. It is the eardrum.

6. Observation.

7. Increased intelligence through increased grey matter in a limited amount of space, the cranium.

8. Greater. Man is a more intelligent animal.

9. Answers will vary. Human brains are proportionally larger, with the cerebrum completely covering the cerebellum, and they also have more convolutions, sulcus and gyrus, than a pig's brain.

Review: pages 433 - 434

Fill in the blanks

1. cornea
2. pupil
3. tympanic membrane
4. corpus callosum
5. blind spot
6. nictitating membrane
7. retina
8. aqueous humor
9. dura mater
10. sulcus

Essay: drawing with labels.

46. Exercise: Your Touch Receptors

Exercise: pages 435 - 440

1 & 2. Answers will vary depending upon the area explored.

3. Less sensitive. Hairs seem to magnify, or increase, the touch of an object.

4. Complement. It seems that hairs, when bent, function like fulcrums to magnify the sensation of touch. In addition, each hair follicle has a nerve ending. The combination is a magnification of the message sent to the brain.

5 & 6. Observation.

7. Genetic inheritance: people inherit distribution and effectiveness of touch receptors.

   Musculature: the more muscles in an area, the further apart are the receptors in that area.

   Sunburn or tan: tend to dull the response of receptors.

   Fat: the more fat, the further apart are the receptors in that area.

8,9,10,11,12,13,14,& 15. Observation.

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Short answer

1. Threshold level is the level at which the receptor passes on its stimulus to the central nervous system. Threshold levels can be excited by one stimulus, if it is strong enough, or by a series of stimuli, if their cumulative effect is strong enough.

2. Other nerves, such as the nerve endings in hair follicles, can add to the stimulus of a neuron, and thereby magnify the original stimulus sent in by a sensory receptor. Therefore, less stimulus is needed from the nerve ending to excite the neuron, because the cumulative stimulus from the sensor and the root hair nerves in combination provide the required threshold level for neuron excitation.

3. Obviously, a pain receptor registers pain, and a touch receptor registers touch. Pain receptors are more easily fatigued than touch receptors. They also are further apart on the skin.

4. Touch, pain, heat, cold, balance or body position, movement, and weight discrimination.